THE

POPULAR SCIENCE MONTHLY.

JUNE, 1876.

LINGUAL DEVELOPMENT IN BABYHOOD.[1]

By H. TAINE.

THE following observations were made from day to day and taken down on the spot. The subject of them was a little girl, whose mental development took the ordinary course, being neither precocious nor the reverse.

From the first, probably by reflex action, this child cried incessantly, kicked, moved all its limbs, and perhaps all its muscles. It was also doubtless by reflex action that, during the first week, she moved her fingers, and even grasped for some length of time the finger of another person. Toward the third month, she began to touch with her hands, and to stretch out her arms, but did not yet know how to guide her hand; she essayed movements of the anterior members, experiencing the consequent tactile and muscular sensations—nothing more. In my opinion, out of this enormous multiplicity of movements, continually repeated, will be separated, by gradual selection, intentional movements having an object and attaining it. During the last fifteen days (age, two and a half months) I have observed one movement which is plainly an acquired one: on hearing its grandmother's voice, the infant turns its head in the direction from which the sound proceeds.

There is the same spontaneous training for the use of the voice as for movements. The vocal organ acquires dexterity just as the limbs do. The child learns how to produce such or such a sound just as it learns how to turn the head or the eyes, i. e., by constant efforts.

Toward the age of three months and a half, while in the country, the child was brought into the open air, and laid upon a carpet spread in the garden. Here, lying on her back or on her face, she for hours at a time would work with all her limbs, uttering a multitude of differ-

[1] Translated from *Revue Philosophique* by J. Fitzgerald, A. M.

ent cries and exclamations, consisting exclusively of vowel-sounds; this continued several months.

By degrees consonants were added to the vowels, and the exclamations became more and more articulate. This process resulted in a sort of prattle of great diversity and completeness, which would be kept up for a quarter of an hour at a time, and repeated ten times a day. The sounds (vowel and consonant), which at first were vague and very hard to discriminate, became more and more like those uttered by adults, and the series of simple cries came to be, in some measure, like a foreign language which we do not understand. The infant is pleased with its prattle, like a bird; one can see that she is happy—that she smiles with pleasure—yet it is nothing better than the chirruping of a bird as yet, for the child does not attach any meaning to the sounds she utters. (Age, twelve months).

She has acquired thus much, in great measure, by her own endeavors and unassisted, but she has gained a little by the aid of others and by imitation. First, of her own accord she produced the sound *mm;* this amused her—it was for her a discovery. So, too, she of herself produced another sound, *kraaau*, emitted from the windpipe in deep gutturals. These two sounds were repeated several times in succession in the hearing of the child; she would listen attentively, and now she repeats them at once on hearing them. The same is to be said of the sound *papapapa*, which she at first uttered several times at random and by herself, and which was then repeated to her a number of times, in order to fix it in her memory. She soon uttered this sound at will, with easy, unerring execution (though without understanding what it meant), as simple prattle. In short, example and education have served only to call the child's attention to sounds which she herself was already attempting to make; to direct her preference to these, to make them uppermost among the host of similar sounds. But the initiative all came from herself; and the same is to be said with respect to gesture. For months she of her own accord attempted all the movements of the arms, flexion of the hand at the wrist, bringing the hands together, etc. Then, after instruction and repeated effort, she learned to clap hands, to hold up the two hands, as in the gesture of astonishment, etc. Example, instruction, and education, are only channels in the bed of which the stream flows; its source lies higher.

To see that this is the case, one has only to listen to her prattle for an hour: it is wonderfully flexible. I am satisfied that here every shade of emotion—surprise, joy, vexation, sadness—finds expression in varieties of tone; herein she equals or even surpasses the adult. On comparing her with animals, even those best endowed in this way—such as the dog, parrot, singing-birds—I find that, with a less-extended gamut of sounds, she far surpasses them in the fineness and the abundance of her expressive intonations. Delicacy of impressions and deli-

cacy of expressions are the distinctive characteristics of man as compared with animals: here is the origin of language and of general ideas. Among animals, man is, what some great and ingenious poet is among laborers and peasants: in a word, he is cognizant of a multitude of shades and tints, even to a whole class of shades, which are unnoticed by them. This is further seen both in the kind and in the degree of man's curiosity. It is easily seen that, commencing with the fifth or sixth month, infants, during the succeeding two years or more, give all their time to making experiments in natural philosophy. There is no animal, not even the cat or the dog, which makes such continual study of all bodies within its reach. Every day, the infant of whom I speak (age twelve months) touches, feels, turns over, lets fall, tastes, and experiments upon, whatever comes under its hand; whatever the object may be—a ball, doll, rattle, toy—once it is sufficiently known, the infant leaves it alone: it is no longer a novelty; there is nothing more to be learned from it; it no longer interests the child. This is simple curiosity; the child's physical wants, its desire of food, have nothing to do with the matter. It would seem as though already in its little brain each group of perceptions tends to complete itself, as in the brain of a child that possesses language.

She does not yet pronounce any word to which she attaches a meaning, but there are two or three words to which she attaches a meaning on hearing them uttered. She daily sees her grandfather, whose portrait, far less than life-size, but a very good likeness, has often been shown to her. During the past two months or so (from the age of ten months), when any one asked her the question, "Where is grandfather?" she turns to the portrait and laughs at it. Before her grandmother's portrait, which is not so good a likeness, she makes no such gestures, nor does she give any token of knowing what it is. For a month past (from the age of eleven months), whenever she is asked, "Where is mamma?" she turns toward her mother. So, too, with her father. I would not go so far as to affirm that these three actions transcend animal intelligence. A little dog, who sits by my side, in like manner understands what is meant when he hears the word *sugar:* he will come from a distance to get his morsel. In all this there is nothing but association: in the case of the dog, between a sound and a certain taste-sensation; in that of the infant, between a sound and the shape of an individual face; the object designated by the sound is not yet a general character.

I believe, however, that now (age, twelve months) a step farther has been taken; witness the following circumstance, which for me is decisive: This winter the child was daily taken to her grandmother's, and the latter very frequently showed her a copy, in colors, of a painting by Luini representing a nude Infant Jesus. On showing her this picture she was told that "this is baby." During the last eight days, whenever, in some other room, we ask her, "Where is baby?"

(meaning herself), she turns toward any picture that may be there, whether it be a painting or an engraving. Hence "baby" signifies, for her, some general notion, whatever paintings and engravings of persons or landscapes may possess in common; i. e., if I am not mistaken, "baby," in her mind, signifies *something variegated in a shining frame.* Indeed, it is plain that the objects painted or designed within the frames are so much Greek to her, while she must be deeply impressed by the glittering frame and the patches of color, light, and shade, within its border. Here, then, we have her first general term; the meaning she gives it is not ours, but nevertheless it is evidence of original work done by the infantile understanding. For, though we have supplied the word, we have not supplied the meaning.

(Age, fourteen months and three weeks.) The gains of the last six weeks have been notable: besides the word "baby" she now understands several others, and of these she pronounces five or six, giving to each a meaning of its own. Mere prattle is succeeded by a beginning of intentional and determinate language. The principal words pronounced by her now are *papa*, *maman*, *tété* (by which she means *nurse*); *oua-oua* (her term for *dog*), *koko* (hen, cock), *dada* (horse, wagon), *mia* (cat, kitten), *kaka*, and *tem.* She acquired earliest the two words *papa* and *tem:* this latter word is very curious, and well worthy of serious consideration.

For fifteen days she pronounced *papa* without a purpose, without a meaning, as simple prattle, and as an easy and amusing exercise of articulation. Later came association between this name and the image or perception; and then the portrait or the person of her father brought to her lips the sound *papa*, and this same word, when pronounced by another, awoke in her the memory, the mental image of her father. Between the two states just noticed there exists an insensible transition, so that, at certain times, the first state still persists after the second state has been attained; at times she still plays with a sound, though she understands its sense. This is very easily seen with respect to some of her later acquisitions, for instance the word *kaka.* This word she often repeats without purpose or intent, as prattle, much to the displeasure of her mother. Again, she frequently utters the word purposely, when occasion offers. Further it is evident that, as in the case of the word "baby," she has extended the meaning of this term. Thus, for instance, on seeing in a flower-bed the track of moistened earth left by a watering-pot, she repeated this word again and again with evident appreciation of its meaning. For her it signifies *what wets.*

She shows great capacity for imitating sounds. She has seen and listened to fowls, and now repeats their *koko* far more accurately than we can do it, with the guttural intonation of the animals themselves. This is simply a faculty pertaining to the windpipe, but she possesses another faculty which is far more striking, a faculty that is *par excel-*

lence human, namely, the power of noting analogies. This is the fountain-head of general ideas and of language. We point out to her on the walls of a room the figures of birds painted red and blue, a couple of inches in length, saying once only, "Look at the kokos." She was at once conscious of the resemblance, and for half a day she took the liveliest pleasure in being carried up and down along the walls of the room, enthusiastically crying out, at the sight of each bird, *koko!* No dog, no parrot would ever act thus, and, in my opinion, we have in this fact the essence of language. Other analogies she perceives with equal readiness. The first dog she ever saw was a little black one belonging to the house, who barks frequently; from him she framed the word *oua-oua.* Very soon, with but slight assistance from those around her, she applied this word to dogs of all sizes and of every breed that she saw in the street; later she applied it to porcelain figures of dogs—a still more noteworthy fact. Nay, on seeing, day before yesterday, a month-old kid, she called it *oua-oua*, thus naming it after the dog, which is the nearest form, rather than after the horse, which is too big, or the cat, which has a different gait.[1] Herein we perceive a trait characteristic of man: two very dissimilar successive perceptions leave a common residue, a distinct impression, solicitation, impulsion, which results in the invention or adoption of some mode of expression, either by gesture, cry, articulation, or name.

I come now to the word *tem*, one of the most noteworthy and one of the first pronounced by her. All the other words are probably *attributives*, to use the language of Max Müller,[2] and a person has no difficulty in discovering their meaning; this is probably a *demonstrative*, and, as we had no term with which to translate it, we took several weeks to discover its meaning.

At first, and for more than two weeks, the child pronounced this word *tem* as she did the word *papa*, without giving to it any precise meaning; she thus practised dental articulation followed by a labial, and the thing afforded her some amusement. By degrees the word became associated in her mind with a definite intention, and at present it means for her *give*, *take*, *see*, *look*. She pronounces it very perfectly, several times in succession, and with earnestness, her aim being now to get some new object which she sees, again to have some one take her up, or to attract attention to herself. All these meanings are comprised in the word *tem*. It may be that it is a form of the word *tiens*, which had often been addressed to her in a somewhat similar sense. But I am rather inclined to suppose that this word was coined by herself to express her principal desires, viz., to be taken in

[1] When the Romans first saw the elephant they called it the *Lucanian ox*. Thus, too, savage tribes that had never before seen a horse gave that animal the title of *big hog*. (*See* Müller's "Lectures on Darwin's Philosophy of Language.")

[2] Lectures on the "Science of Language," sixth edition, vol. i., p. 309.

the arms, to get the objects she wants, and to attract notice. If such is the case, then this word is a *natural vocal gesture.* This view is rendered more probable by the fact that she possesses other words, of which more anon, and which are evidently the products, not of imitation, but of invention.

(Fifteenth to seventeenth month). Great progress made; the child has learned to walk, and even to run. She is gaining new ideas every day, and understands a number of phrases, such as these: "Fetch the ball;" "Go and *doudou* to the lady" (i. e., fondle her and let her kiss you); "Come and stand between papa's legs;" "Go down there;" "Come here," etc. She is beginning to distinguish between the tone of anger and that of pleasure; she quits doing anything forbidden with severe countenance, or with voice expressive of disapproval; of her own accord she frequently shows a desire of being fondled. But she has learned or invented but few new words recently. Her chief new words are *Pa* (Paul), *Babert* (Gilbert), *bébé* (baby), *béé́* (nanny-goat), *cola* (chocolate), *oua-oua* (anything good to eat), *ham* (eating, I want to eat). There are a number of other words which she understands, but is unable to pronounce, such as grandfather, grandmother. Her vocal organs, not being sufficiently practised, do not as yet reproduce all the sounds she knows, and to which she attaches meanings.

Cola (chocolate) was one of the first dainties she ever tasted, and she prefers it to all others. She gets a lozenge daily during her visits to her grandmother; she knows the box in which the bonbons are kept, and keeps pointing toward it until it is opened.

Bébé.—We have spoken of the curious meaning she at first gave to this word; by degrees, under the influence of education, she has come nearer to its ordinary sense. Other infants have been shown to her, and called *bébé*; she herself has also been called by this name; now she answers to it. She has been shown the reflection of her own face in a mirror, and told to look at *bébé*, and now she goes herself to the glass, and, on seeing the image, laughs and calls "*bébé!*" Starting from this, she gives the name of *bébé* to miniatures, pictures, and statuettes. Here again education has produced a result that had not been anticipated: the general character perceived by the child is not the one that we could have desired her to perceive. We have taught her the sound, and she has invented the meaning.

Ham (eating, I want to eat).—Here she originated both the sound and the sense. This sound she first uttered during her fourteenth month. For weeks I took it to be mere prattle, but at last I noticed that it was uttered always, without exception, when food was in sight. Now she never fails to say *ham* whenever she is hungry or thirsty. This again is a *natural vocal gesture.*

Oua-oua.—It was not till three weeks ago (end of the sixteenth month) that she employed this word in the sense of something good to eat. For a while we did not understand what it meant, for the

same sound had long been used by her, but always to signify *dog*. In this new meaning the sound has oscillated between *va-va* and *oua-oua*. In all probability the sound here written *oua-oua* is for her twofold, in accordance with the two different meanings she attaches to it. But my ear does not detect this difference. The senses of infants, which are less obtuse than ours, perceive delicate shades which we do not distinguish. It is worthy of mention that she strictly applies this term *oua-oua* to food and drink; the act of eating or drinking is expressed by *am*, or *ham*. Thus, when she hears the dinner-bell, she says *am*, not *oua-oua;* but at table, when seated before some article of food, she says *oua-oua*, and much less frequently *am*.

On the other hand, the word *tem* (give, take, look), of which I have already made mention, has during the past two months fallen into desuetude. She never pronounces that word now, nor can I find that she has replaced it by any other. Doubtless the reason of this is, that we did not care to learn it: it answered to none of our ideas, inasmuch as it coupled three very distinct notions.

On summing up the facts already stated we reach the following conclusions; it remains for others to modify them by observing other infants:

At first the infant cries, and employs its vocal organ in the same way as its limbs, spontaneously and after the manner of reflex action. Spontaneously, too, and because it finds pleasure in being active, the infant later exercises its vocal organs in the same way it exercises its limbs, gaining the perfect use of them by repeated essays and by a process of selection. From inarticulate it thus passes to articulate sounds. The variety of intonations which it acquires evinces in the child great delicacy of impression and of expression; hence the faculty of forming general ideas. All we do is to aid it in grasping these ideas by suggesting our words. To these the infant attaches ideas of its own, generalizing after its own fashion rather than ours. Sometimes it invents not only the meaning of a word, but the word itself. Several vocabularies may succeed to one another in its mind, new words obliterating old ones; several different significations may successively be attached to one word; several words invented by itself are natural vocal gestures; in short, it learns a ready-made language as a true musician learns counterpoint, or as a true poet learns prosody: the child is an original genius, which adapts itself to a form built up bit by bit by a succession of original geniuses. If there existed no language it would discover one, or find an equivalent.

This series of observations was interrupted, owing to the misfortunes of the year 1870. The following notes may serve to show the mental state of an infant: in many respects this state is that of primitive peoples in the poetical and mythological period

A water-jet, which this infant saw daily for three months, always gave her new pleasure. The same is to be said of the flow of a river

as seen from a bridge. The flashing, running water was plainly for her an object of extraordinary beauty, and she would keep exclaiming, "Water, water" (age, twenty months). A little later (thirty months) she was profoundly impressed on seeing the moon. She wanted to look at it every night. When she walked abroad it seemed to her that the moon also was moving, and this discovery gave her delight; as the moon made her appearance in different localities, according to the hour, being seen at one time in front of the house, and again in the rear, she would exclaim, "Another moon! another moon!" One night (age, three years) she wanted to know where the moon was, and, on being told that it had gone to bed, she asked, "Where, then, is the moon's nurse?" All this very closely resembles the emotions and conjectures of childlike races; their profound wonderment in presence of the great phenomena of Nature; the influence exerted upon them by analogy, language, and metaphor, leading them to form myths of the sun, the moon, etc. Suppose such a state of mind to be universal at any period, and we can readily foresee what religious ideas and legends would be the result; in fact, we have instances of this process of development in the Vedas, the Edda, and even in Homer.

If we speak to the child of an object at some little distance, but which she can represent to herself definitely enough, having seen the object itself or something like it, her first question always is: "What does it say? What does the rabbit say? What does the bird say? What does the horse say? What does the big tree say?" Whether it be an animal or a tree, she always treats the object as a person; wants to know what it thinks, what it says. By a spontaneous induction, she pictures it as like herself or like us—humanizes it. This same tendency is found among primitive races, and it is all the stronger the more primitive they are.

It requires long time and many an effort for the infant to attain to ideas which to us appear simple. When this child's doll had its head broken she was told that now the doll was dead. One day her grandmother said to her: "I am old, and shall not remain long with you; I shall die." "Your head will be broken, then." This she repeated several times. Even yet (age, three years and one month), to be dead means, for her, to have a broken head. Day before yesterday a magpie that had been killed by the gardener was tied to the top of a pole for a scarecrow; on being told that the pie was dead the child wished to see it. "What does the pie do?" she asked. "She does nothing; she will never stir again, she is dead." "Oh!" For the first time the idea of final immobility has entered her mind. Now let us suppose a people to stop at this idea, and to have no other definition of death than this. For them the Beyond will be the Sheol of the Hebrews—the place where the motionless dead live a vague sort of life. For her *yesterday* means *in the past*, and *to-morrow* means *in*

the future; neither of these terms signifies for her just one day. Here, again, she gives too large a signification to words. And an infant scarcely employs a single word that is not destined later to receive a more restricted meaning. Like primitive peoples, infants incline to conceive large and general ideas. The child presents, in the transitional state, mental characters which we find in the fixed state in primitive civilizations, just as the human embryo presents in the transitional state physical characters which are found in the fixed state in certain lower classes of animals.

NATURAL TRUMPET OF THE CRANE.

By FRANK BUCKLAND.

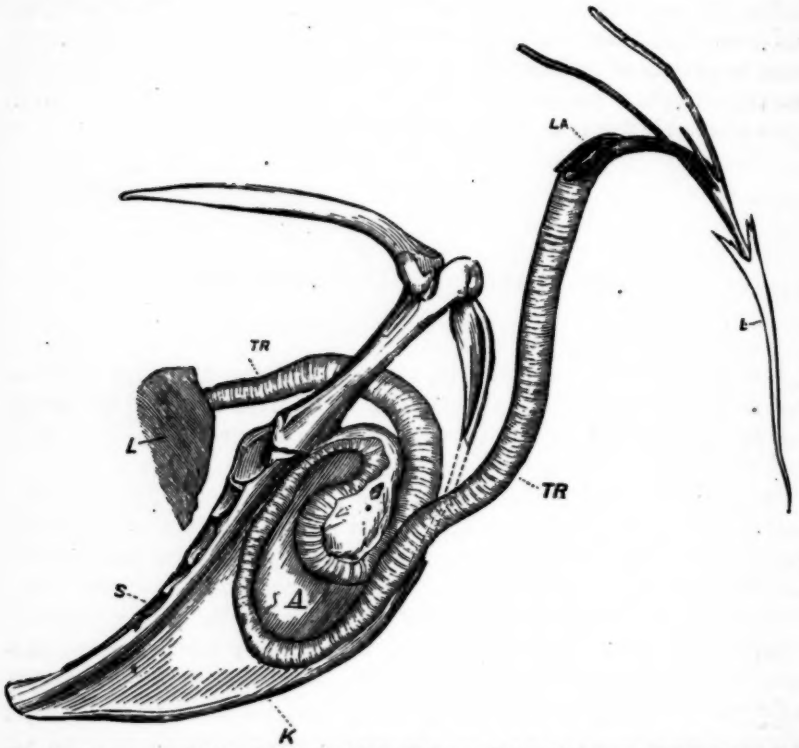
SPORTSMEN and naturalists, both at home and abroad, would do well to collect not only the skins of birds, but also to search for any peculiarity which may happen to occur in their internal structure, especially the bones and the larynx.

Some weeks since, when calling upon my friend Mr. Jamrach, the animal-dealer, I observed in the back-yard, on the dust-heap, a number of dead birds. Among them was the body of a very large crane. Mr. Jamrach allowed me to take this home, and I made several preparations of it. We now figure the very remarkable trachea, or windpipe, of this bird. In an ordinary bird, such as a chicken, when cutting open the skin of the throat, it will be found that the trachea forms a continuous tube, going in a direct line from the mouth to the lungs, where it bifurcates. In the crane this is not the case. Instead of passing between the two bones ordinarily known as the merry-thought, it becomes convoluted in a very remarkable manner. If this convolution had been placed immediately under the skin, first of all it would have been cumbersome to the bird; and, secondly, there would have been a great likelihood of its becoming injured. The breastbone, therefore, has been hollowed out in the middle in such a manner as to keep the trachea packed up in a beautiful box of bone. Inside this box of bone there are about thirteen inches of the trachea. The trachea enters this bony box at its lowest margin; it then runs along the bottom and ascends to the top; then takes a very sharp turn, and again descending to the bottom of the box joins the lungs in the usual way. In life this trachea is not fixed in the box, but is capable of extension and prolongation; in fact, is almost as elastic as India-rubber.

The diagram will explain this.

The curious cartilaginous-like material—reminding us of mosaic work—of which the trachea is composed, differs much in pattern in its various portions, the rings being single near the mouth, while a few

inches farther they appear to be double. A model of them at this part of the tube can be obtained by locking the fingers of both hands one into the other. Just as the trachea leaves the bony box it is considerably enlarged.



T is the tongue, attached to the bifurcated hyoid bone; *LA* is the larynx; *TR* is the trachea immediately before it buries itself in the peculiar hollow box of bone, *A*. In this box, as already described, it becomes convoluted; then, leaving the box, it enters the cavity of the chest, and joins the lungs at *L*.

Of course, the use of this curious structure is to produce those wonderful sounds which are peculiar to the crane. In fact, it is a portion of a *cornet-à-piston* or trombone, and is, no doubt, worked by some very delicate muscles. I have never had the pleasure of seeing cranes fly in the air, but I am told that the noise they make is very wonderful. We read: "Cranes range, according to the season, from the north of Europe to the south of Asia, and north of Africa, and in the latter country they are said to extend their migrations as far as the Cape of Good Hope. On these excursions they fly high in the air, though they experience some difficulty in getting on the wing from the ground. Before taking their spring they run some paces, raise themselves a little at first, and then unfold a powerful and rapid wing. In the air they form very nearly an isosceles triangle, possibly for the purpose of cutting the element with greater facility. When attacked

by an eagle, or the wind is likely to break their order, they close in circles. Their passage frequently takes place during the night, which is known by their sonorous voice, which announces it; and the head of the troop often utters, to indicate the route he is taking, a cry of appeal to which all his followers answer. Their voices, even on these nocturnal voyages, are exceedingly loud—probably owing to the length of the windpipe and the convolution near its bronchial extremity. When they cry during the day they are generally understood to forebode rain, as is the case with the cries of many other birds which feed partially on those worms which the approaching humidity brings to the surface—not only when the rain actually falls, but when, from the changed state of the air, the evaporation is much diminished. When they are peculiarly noisy and tumultuous, and fly near the ground, occasionally alighting, it is considered as a pretty certain indication of a tempest. On the other hand, when they rise high, and fly onward in regular order, it is regarded as a sign of fine weather."

That great observer, Virgil, has used the simile of cranes in flight in a grand passage in the tenth "Æneid," to give an idea of the Greeks and Trojans charging each other in the battle-field:

". . . . Clamorem ad sidera tollunt
Dardanidæ e muris: spes addita suscitat iras:
Tela manu jaciunt. Quales sub nubibus atris
Strymoniæ dant signa grues atque æthera tranant
Cum sonitu, fugiuntque Notos clamore secundo."

[The Trojans, from their walls, raise acclamations to the stars. Additional hope rouses up their fury. Darts from their hands they hurl, as under the black lowering clouds Strymonian cranes give the signal and swim along the skies with obstreperous din, and from the stormy south winds with joyous clamor fly.]

I consider the marvelous natural trumpet of the crane to be a most beautiful provision given by the Creator to these wild birds to enable them to keep their ranks, and not lose each other when migrating. In fact, we men have adopted the idea by using trumpets. It often happens that the dust at a field-day is so great that very little can be seen, while it would be impossible for the human voice to be heard; trumpets, therefore, come in here of the greatest service, especially to direct movements of cavalry. In the same way, the cranes might possibly lose each other when flying in the wilderness of space of the vast firmament of ether, and, were it not for their being able to signal to each other, they would be unable to travel with facility either at night, or when passing through clouds and fogs.

A few days since a valued correspondent in Ireland sent us the breastbone of a Hooper swan. I have dissected this, and find the trachea convoluted in a manner very similar to that of the crane.

There is a legend that when a swan is dying he becomes musical.

The origin of this legend probably is the trumpeting of the wild-swan. This our friends can hear in the Zoölogical Gardens; it is a melancholy sound, and may be thus written—"hwoo hwoo." The tame swan has not this structure of the windpipe, showing, therefore, that it is a distinct species. As the trumpet is useful to the crane, so also is it to the swan. They fly very high, in order that the "hawks should not gain the sky" of them; they always fly with the wind, and when going with a stiff breeze are said to go at a pace of a hundred miles an hour.

Many of our friends have probably heard that amusing bird, the trumpeter (*Cariama cristata*). Mr. Cholmondeley, of Condover, has a very tame specimen, that wanders all over his house, and goes out walking in the garden with him. In the trumpeter-bird there is a musical apparatus of another kind. The note of the trumpeter is very agreeable to the ear.

I have lately dissected a Merganser. I find that his trachea is also peculiar: it swells out considerably about the third of its way down, and at the end it bulges out into a box as large as a walnut. The common duck has a curious larynx. At the bottom of the windpipe will be found a bony dilatation. Our readers should examine this for themselves. The female has not this peculiarity, and, strange to say, although the drake has this very peculiar organism, he is not able to quack—the females only quack; the males give a short hiss. My friend Mr. Bartlett informs me that on one occasion a gentleman sent him this bony box, which the cook had taken out, and said that it was the ossified heart of a duck.—*Land and Water.*

PETROLEUM.[1]

By Prof. H. B. CORNWALL.

ALTHOUGH it has only lately acquired its present important place among articles of commerce, this valuable product of Nature's laboratory has been known for ages, and was used for medicinal and illuminating purposes in ancient times. The petroleum-spring of Zante, one of the Ionian Islands, was mentioned by Herodotus more than 2,000 years ago; and Pliny says that the oil of a spring at Agrigentum, Sicily, was used in lamps. The city of Genoa was formerly lighted from the wells of Amiano, in Parma, Italy.

Prof. A. E. Foote (*American Chemist*, November, 1872) states that Peter Kalm, in his "Travels in North America," published in 1772, gives a map of the Pennsylvania oil-springs in 1771; but, according to H. E. Wrigley, the earliest mention of petroleum in that State

[1] Petroleum, literally *rock-oil*, from *petra*, rock, and *oleum*, oil.

occurred in the report of the commander of Fort Duquesne, 1750, when he witnessed the ceremonies of the Seneca Indians on Oil Creek. A prominent feature of the ceremonies was the burning of the oil as it oozed from the ground.

The oil-spring of Cuba, Alleghany County, New York, called the Seneca Oil-Spring, was described by Prof. Silliman, in 1833, as a dirty pool, about eighteen feet in diameter, covered with a film of oil, which was skimmed off from time to time for medicinal purposes. The so-called Seneca-oil was not from this spring, but from Oil Creek. Hildreth, in 1833, gave an account of the salt-wells of the Little Kanawha Valley, West Virginia, which he says yielded a little oil. In 1840 a well at Burkesville, Kentucky, was described as spouting oil at the estimated rate of seventy-five gallons a minute for a few days, but it then failed entirely (Dana, "Mineralogy," fifth edition, 1869). In 1844 Mr. Murray mentioned the petroleum of Enniskillen, Canada.

About twenty years ago the manufacture of oil from coal and bituminous shales, having been widely extended through the labors of Abraham Gesner and James Young, of Glasgow, began to excite interest in this country, and, according to S. D. Hayes, the first coal-oil offered for sale in this country was made by Philbrick & Atwood, in 1852, at the works of the United States Chemical Manufacturing Company, Waltham, Massachusetts. It was called coup-oil, after the recent *coup d'état* of Louis Napoleon, and was used as a lubricator.

In 1856 the first illuminating oil was made by Mr. Joshua Merrill, from Trinidad bitumen, according to the same authority. According to H. E. Wrigley, however, a refinery was started as early as 1850 by Mr. Samuel Kier, of Pittsburg, Pennsylvania, for the treatment of crude petroleum ("Report on Petroleum of Pennsylvania" for the "Second Geological Survey of Pennsylvania, 1874"). Success being limited only by the small amount available, search for the oil was naturally directed to Oil Creek, and in 1858 Messrs. J. G. Eveleth and George H. Bissell, of New York City, leased one hundred acres of land near Titusville, on the northern border of Venango County, Pennsylvania, and engaged Colonel E. L. Drake, of New Haven, Connecticut, to bore a well. On the 28th of August, 1859, he struck oil at a depth of seventy-one feet (according to some authorities sixty-nine and a half feet), and a pump was adjusted which produced twenty-five barrels a day.

In 1861 the first flowing well was struck by Mr. Funk, on the M'Elhenny Farm, Oil Creek, at a depth of 400 feet. Soon after two more wells were sunk (the Phillips and Empire), flowing 3,000 barrels each daily. Since 1858, in round numbers, 10,500 wells have been bored in Pennsylvania, and oil-wells also exist in West Virginia, Ohio, Kentucky, and elsewhere, with results that will be stated hereafter.

It would not be proper to leave the history of petroleum without

mentioning Prof. B. Silliman's report on Pennsylvania petroleum to Messrs. Eveleth, Bissell & Reed, 1855.

He examined the rock-oil or petroleum of Venango County, and, long before the present processes of refining had been introduced, suggested several very important processes, which have been since followed in its treatment; such as distillation by steam, "cracking," or breaking up of the heavier oils into lighter compounds, its use for making gas, for illuminating purposes, for lubricating, etc.

COMPOSITION.—Petroleum is a mixture of several hydrocarbons, and contains also bituminous materials, sulphur, carbonaceous matter, sand, and clay. Its odor is generally offensive. The color and specific gravity vary greatly. The crude petroleum of Pennsylvania is generally dark-green with a brownish tinge by reflected light; the color of thin layers by transmitted light varies from dark-yellowish to reddish-brown. The oil of Enniskillen is blackish-brown; of Mecca, Ohio, yellow; in the neighborhood of Shamburg, Venango County, Pennsylvania, "black" and "green" oils occur side by side in the same districts; the lubricating oil of White Oak, West Virginia, is yellow; that from Amiano, Italy, is red to straw-color; at Baku the light oil is clear and faint yellow. Pennsylvania petroleum is somewhat thick, like thin sirup, but, although stiffened somewhat by cold, is always fluid. The oil of Pagan, Burmah, is very light, resembling naphtha, as is some of that from Baku.

The specific gravities of different petroleums are as follows: White Oak, West Virginia, 28° to 40° Beaumé; Mecca, Ohio, 26° to 27°; Franklin, Pennsylvania, 30° to 32°; Cuba, New York, 32°; Tidioute, 43°; Pit-Hole, 51°; Pomeroy, Ohio, 51°; Russia, 28° to 40°. The heavy oils command, as a rule, a higher price. Although there is no certainty about their occurrence, the heavy oils have been frequently found at a higher level than the light oils in Pennsylvania, so that this was at one time supposed to be the rule.

The constituents of the mixture known as petroleum are separated from each other by fractional distillation; with care they can be isolated in quite a pure state, but in practice they undergo various decompositions, and are frequently to be regarded rather as *products* than as *educts* of the operations. Some are gaseous at ordinary temperatures, others are liquid, and others solid. They are divided into two classes: one having the formula C_nH_{2n+2}, and belonging to the marsh-gas, or paraffine series; the other, with the formula C_nH_{2n}, belonging to the ethylene series (olefines). They have been carefully investigated by Pelouze and Cahours, Warren, Schorlemmer, and Ronalds, and the results obtained by them are given in the following table, partly compiled from the review of the subject by Prof. S. P. Sadtler, in Prof. Genth's "Report on the Mineralogy of Pennsylvania" ("Second Geological Survey, 1874"). The letters F, R, W, P and C, and S, indicate the observers, Fouqué, Ronalds, Warren, Pelouze and

Cahours, and Schorlemmer. The first and second were found by Fouqué in gaseous exhalations from petroleum-wells at Petrolia (and Fredonia, New York); the third in similar exhalations from wells at Pioneer Run.

MARSH-GAS SERIES.—FORMULA C_nH_{2n+2}.

No.	NAME.	Formula.	Carbon.	Hydrogen.	Boiling-Point (C.).	Specific Grav. (0° C.).	Observer.
1	Methyl hydrid (methan)...	CH_4	75	25	A gas.	.559	F.
2	Ethyl hydrid (æthan).....	C_2H_6	80	20	"		F.
3	Propyl hydrid (propan)....	C_3H_8	81.81	18.19	−17°		F. R.
4	Butyl h. (normal butan)...	C_4H_{10}	82.8	17.2	0	.600	W.
5[1]	Pseudo-butan.....	"	"	"	17		
6	Amyl h. (normal peutan)..	C_5H_{12}	83.33	16.67	37–39	.645	W.
7	Dimethyl-propan.....	"	"	"	30.2	.626 (17°)	P. & C., W., S
8	Hexyl h. (normal hexan)...	C_6H_{14}	83.72	16.28	68.5	.689	P. & C., W., S.
9	Æthyl-isobutyl.....	"	"	"	61.3	.676	W.
10	Heptyl h. (normal septan)..	C_7H_{16}	84	16	98.1	.780	W., S.
11	Æthyl-amyl.....	"	"	"	90.4	.718	W., S.
12	Octyl h. (normal octan)....	C_8H_{18}	84.21	15.79	127.6	.752	W.
13	An isomer of No. 12.....	"	"	"	119.5	.737	W., P. & C.
14	Nonyl hydrid (nonan).....	C_9H_{20}	84.38	15.62	150.8	.756	W.

Pelouze and Cahours carry the marsh-gas series to $C_{16}H_{34}$, but Warren concluded that it terminates with C_9H_{20}, and that the oils of higher density and atomic numbers belong to the ethylene series.

On inspecting the above table it will be seen that numbers 4, 7, 9, 11, 13, and 14, have a common difference of about 30° C. between each in succession, in regard to their boiling-points; and that numbers 6, 8, 10, and 12, have a similar common difference, and are each about 8° higher in their boiling-points than the ones next below them. On this account, Warren divided them into two groups; but he included here another C_4H_{10}, with a boiling-point of 8 to 9°, which is, according to Sadtler, a mixture of the two given in the table.

Besides the members of the marsh-gas series given above, American petroleum yields liquids boiling above 300° C., which on cooling yield a solid mass called paraffine, white and transparent when pure. It probably is a mixture of the higher members of the series C_nH_{2n+2}, and on heating in a sealed tube is converted into a mixture of several paraffines and olefines of lower molecular weight, liquid at ordinary temperatures (Fownes).

Of the ethylene series, Warren has found in Pennsylvania petroleum, decylene, $C_{10}H_{20}$, boiling-point 174.9°; undecylene, $C_{11}H_{22}$, boiling-point 195.8°; and bidecylene, $C_{12}H_{24}$, boiling-point 216.2°; these have a difference of about 20° C. in their successive boiling-points.

No higher series of hydrocarbons is yet known from Pennsylvania petroleum, but members of the benzol series, C_nH_{2n-6}, have been found in other petroleums. Thus De la Rue and Müller, in 1856, found benzol, toluol, and xylol, in Rangoon tar; Bussenius and Eisenstuck discovered xylol in petroleum from Sehnde, Hanover; Pebal and Freund detected benzol, C_6H_6, toluol, C_7H_8, xylol, C_8H_{10}, cumol, C_9H_{12}, and cymol, $C_{10}H_{14}$, in naphtha from Boroslaw, Galicia; De la

[1] Not yet obtained in a pure state.

Rue and Müller found naphthaline, $C_{10}H_8$, in Rangoon tar; and, finally, a member of the anthracene series, C_nH_{2n-18}, has been found in the last products of the distillation of petroleum for paraffine-oil. It is probably formed by destructive distillation of the petroleum, and has been called *thallene* or *viridine* by Prof. H. Morton, who investigated especially its fluorescent character.

Petroleum undergoes alteration by *evaporation of its lighter constituents*, leaving viscid or solid bitumen, containing more or less paraffine; by *oxidation of some hydrogen*, giving rise to ethylenes, benzols, or naphthalenes; and, by the additional *absorption of oxygen*, forming true asphaltum. Of this latter class are the grahamite of West Virginia and the albertite of Nova Scotia. The grahamite I believe to have been altered before reaching its present level, for reasons which cannot be given here. Mr. W. P. Jenney has made some interesting experiments on the oxygenation of petroleum and the formation of artificial oxygenated hydrocarbons resembling natural products (*American Chemist*, April, 1875).

Occurrence of Petroleum.—It occurs in rocks of nearly all ages, from the Lower Silurian up; most abundantly in shales and sandstones; also to some extent in limestones. Sometimes it impregnates the whole stratum; sometimes it collects in subterranean cavities and fissures. In the Rangoon and Caspian regions the oil occurs near the surface in clayey soil, and collects in shallow pits. A noted foreign locality is Ye-nan-gyoung, in Burmah, where the wells are narrow shafts, 180 to 300 feet deep, and large enough for a man to work in. The oil is drawn up with a bucket and windlass, and as many as 1,000,000 barrels are annually obtained. In Persia oil is largely found at Baku, on the west shore of the Caspian; China yields a small amount of oil; Japan has small and undeveloped districts; New Zealand, also, shows indications. In the Caucasus, Russia, surface-wells have long been worked, and lately wells have been sunk with great success. In Galicia, Austria, are wells yielding largely; and Alsace and Hanover have produced some oil. Petroleum has likewise been found in Peru, Ecuador, Southern Mexico, San Domingo, Trinidad, and Nova Scotia, in small quantities.

The petroleum district of Canada West is in Lambton, Bothwell, and Kent Counties (H. E. Wrigley), and in Ontario. The average production is not over 2,500 barrels daily. It occurs mainly in the Corniferous limestone of the Lower Devonian, but is also found in greater or less quantity in the Bird's-eye limestone of the Lower Silurian, and the Lower Helderberg limestone of the Upper Silurian. The cavities of Orthocerata in the Trenton limestone (Lower Silurian) at Pakenham, Canada, frequently hold small quantities of petroleum. In Canada East there is a petroleum district on the St. John's River, not far from Gaspé Bay.

In the United States oil is very abundant in Western Pennsylva-

nia, and has been found in considerable quantity in West Virginia, Ohio, Kentucky, and Tennessee. It has also been found, but in small quantities, in New York State, near Chicago, in Michigan, Indiana, Colorado, and California. The oil of Southern California comes from Tertiary shales, and is said to contain no paraffine.

The Upper Oil-Region of Pennsylvania begins in the vicinity of Tidioute, on the Alleghany, in Warren County, and runs southwest to Titusville, thence nearly south, along Oil Creek, into Venango County to Oil City, and thence southwest to Franklin. East Sandy, on East Sandy Creek, is at the extreme southeast edge of this field, and forms the only connecting link between the upper and lower oil-fields of the State. The principal points in this upper region are Tidioute, Triumph, and Economy, in the Tidioute District; West Hickory, New London; the Titusville District, including the Drake well; Church Run, Pit-Hole, Shamburg, Petroleum Centre, Rouseville (between these two places were the Blood well, of 1,000 barrels daily, and the Phillips well, which once flowed 3,940 barrels in twenty-four hours, and has produced over 500,000 barrels), Oil City, Sage Run, and Franklin. The Valley of Oil Creek, within a length of twenty miles, produced over $110,000,000 worth of oil, from an actual area of less than three square miles.

The Lower Oil Belt begins at Triangle City, Beaver Creek, Clarion County, and runs southwest twenty-one miles to St. Joe, in Butler County, and is the greatest producing area so far found (H. E. Wrigley, *op. cit.*). In 1866 rock with some oil was struck at Brady's Bend at a depth of 1,100 feet, giving rise to further investigation of the river above, which resulted in the discovery of a sand-rock of 57 feet thickness, at a depth of 960 feet, on the Alleghany River at Parker's Landing. A number of wells that had been supposed failures were afterward drilled to the proper depth, with great results.

The oil-bearing rock of Pennsylvania is a sand-rock, of which different strata are struck at different depths.

The operators speak of these as the first *sand*, second *sand*, and so on. After going through loose soil and a shale or slate-rock, the *first sand* is struck generally near the surface in the upper oil-regions (at a depth of 71 feet in the case of the first well sunk, the Drake well); 100 to 200 feet below this is the *second sand;* at 300 to 400 feet more the *third sand*, and then a *fourth* and *fifth* sand at intervals of about 150 feet. These sand-rocks are generally light-colored, and are separated by slate and other dark sand-rocks.

The heavy oil of Franklin comes from a sand-rock 260 feet deep, and from 50 to 80 feet in thickness. The lower sand-rocks are said to produce very bright, pure oils. Only 39.5 square miles of the 3,115 miles of the oil-region of Pennsylvania are actually productive.

The West Virginia oil-wells occur along an anticlinal extending from the borders of Southern Ohio through Wood, Wirt, and Ritchie

Counties, between thirty-five and forty miles. No oil is found in the horizontal rocks, but it occurs along the disturbed and broken, tilted strata on the edges of the line of uplift. This same belt runs north into Ohio, through Washington and Morgan Counties into Noble County. Volcano, White Oak, and Burning Springs are the principal points in West Virginia. The oil is found in subcarboniferous rocks, ascending to them from the underlying Devonian.

In Ohio there is another oil-belt, west of the above, beginning in Perry and Morgan Counties on the north, and running south through Athens into Meigs County; and in Cuyahoga and Trumbull Counties are oil-regions closely related to those of Western Pennsylvania. The "Mecca" oil, a valuable lubricating oil, occurs in the Mecca Oil Rocks (Berea grit and Bedford shales) of Trumbull County, Ohio. The total production of Ohio and West Virginia is not over 500 barrels daily (Wrigley).

The Kentucky oil-district is mainly in Barren and Cumberland Counties, with a small adjoining tract south of it in Overton County, Tennessee. A well in Cumberland County, 191 feet deep, produced 300 barrels daily. The abundant supply from Pennsylvania and the difficulty of transportation have prevented these regions from becoming well known.

Origin and Source of Petroleum.—At first it was held by many that petroleum was a result of distillation from the bituminous coals, which were found in its vicinity, and this belief was strengthened by the fact that some of the very bituminous coals, such as Cannel and Boghead coal, afforded large quantities of similar oils on being distilled; but, although this is very probably the source of a small amount of oil, yet the larger part of it is now believed to derive its origin from rocks lying below the coal-measures, since the oil-bearing rocks are mostly older than the carboniferous formations.

Some investigators have ascribed a vegetable origin to petroleum, but most authorities agree in attributing it to animal as well as vegetable agencies. Shales are the most common oil-bearing rocks, and in their formation the organic materials would be finely divided and protected from oxidation. The oil-bearing shales commonly show few vegetable remains, and Dana observes that the absence of distinct fossil animal and vegetable remains points to an abundance of delicate water-plants or infusorial or microscopic vegetable life as the source of the organic material contained in them. Limestones, on the other hand, are frequently full of animal fossil remains, showing an animal origin for the oil in them, although it is by no means agreed that the petroleum in certain limestones was derived from organic remains in the limestones and not from other strata below them. In whatever shape the finely-divided material was originally present, it would be finely diffused through the mud, and protected from atmospheric agencies, and subsequently the hydrocarbons would be formed from them,

probably at but a slight elevation of temperature, produced by the same agencies which have caused elevations in the temperature of the interior of the earth's crust at various points.

Dana has further pointed out how petroleum might be formed by the reactions of the organic vegetable remains alone, the abstraction of some carbon and oxygen, as carbonic acid, accounting for the formation of the lighter oils; while the escape of some marsh-gas from less confined material would account for the heavier oils.

Newberry attributes the disagreeable smell of some limestone-oil to its animal origin, and Dufrenoy alludes to the abundance of fish fossils as a proof that the oil of various European districts was derived from animal remains.

As regards the circumstances favoring the accumulation of petroleum, it appears that there should be a shale or other fine-grained rock forming to protect the organic matter during its deposition, a porous stratum above to be penetrated by the hydrocarbons resulting from the decomposition of the organic matter, and finally another shale or slate above, to prevent the further escape of the volatile products. If the sand-rock which usually forms the porous stratum is filled with fissures, large quantities of oil may collect in these.

The petroleum of Enniskillen, Canada, is ascribed by Hunt to the Coniferous limestone of the Lower Devonian. Many geologists ascribe the oil of Pennsylvania, West Virginia, Ohio, and the rest of this grand oil area, to the black shale or Genesee slate of the Middle Devonian. Dr. J. S. Newberry, in his "Report of the Geological Survey of Ohio," says of the Huron (black) shale of the Middle Devonian in Ohio, that it is bituminous, and contains sheets of asphalt or asphaltic coal. Oil and gas springs are associated with its outcrop, and there is reason to believe that it supplies the wells of Oil Creek, Pennsylvania. Hydrocarbons are the product of spontaneous distillation in the outcrops of the Huron shale in Ohio. It shows traces of marine vegetation, and represents the Gardeau shale of New York, with whatever there is in Ohio of the underlying Genesee slate. Its materials appear to have accumulated in a quiet water-basin, being marine and not terrestrial vegetation. It forms a vast repository of hydrocarbonaceous matter, yielding ten to twenty gallons of oil per ton by distillation.

A line of oil and gas springs marks its outcrop, from Central New York to Tennessee. Emanations of oil and gas occurring from Lower Silurian rocks at Collingwood, Canada, and on the Upper Cumberland River, Kentucky, are associated with similar deposits of black shale representing the Utica shale (Lower Silurian) of New York. The wells of Oil Creek penetrate strata immediately overlying the Huron shale, and the oil is obtained from fissured and porous sheets of sandstone of the Portage and Chemung groups, which lie just over the Huron and offer convenient reservoirs for the oil it furnishes. It is a

well-known fact that wells sunk into the black shale yield no considerable quantity of oil, unless from strata resting upon it.

The foregoing statements, it will be seen, go to substantiate the theory upheld by Newberry, in common with other geologists, that the strata yielding much oil have only served to store the oil which comes from other strata below. T. S. Hunt holds that the petroleum of the limestone of Ontario, Canada, and other localities is largely the result of decomposition of the organic matters in these same rocks, and not of distillation from below. This view Newberry opposes on the following grounds: The Corniferous limestone, from his very extended observations, contains little hydrocarbons; oil and gas springs are rare where it underlies the surface; no considerable quantity of petroleum has been derived from wells in the Corniferous, Niagara, or any other limestone; even at Chicago there are no paying wells. Borings have been unsuccessful in Ohio wherever the Corniferous is the surface rock; and, further, there is no Corniferous limestone where Hunt cites it in Kentucky. There is positive proof that part of the oil comes from a lower horizon, and probably the Canada oil comes from underlying Silurian Collingwood shale. On Oil Creek are the argillaceous shales of the Waverley and Chemung strata, forming the sides and bottom of the valley, and below are several beds of sandstone, with the black shales of the Portage and Genesee still lower. In Ohio these favorable conditions are wanting; the sand-rocks of Oil Creek thin out and give place to fine, impervious, argillaceous shales; the strata become more homogeneous and free from crevices, and hence the oil cannot penetrate them so well. In Cuyahoga County, Ohio, the wells reach down through carboniferous rocks to the Huron shale, but there are no good wells, because the sandstone reservoirs are lacking, and only close-grained shales are present.

Hunt, on the other hand, holds that the petroleum of Southwest Ontario, and probably in other localities, is to be sought in the oliferous limestones of the Corniferous and Niagara formations, both of which abound in indigenous petroleum (*American Journal of Science*, III., ii., 369), which, in the case of the Ontario limestone, he shows cannot have come from overlying strata. He also mentions a well sunk at Terre Haute, Indiana, 1,900 feet deep, which yields two barrels of oil daily; and a second one, very near, which yields 25 barrels. This one is 1,625 feet deep, and passes through 700 feet of coal-measures, 700 feet of carboniferous limestone, with underlying sandstone and shales, 50 feet of Genesee slate (or its equivalent), and at a depth of 25 feet below this the oil-vein was met with in Corniferous limestone. A third well, a mile east, at a depth of 2,000 feet showed no oil.

The truth seems to be, that these limestones may contain a little petroleum indigenous to them, but they have not furnished the grand supplies of very productive regions. Before leaving this part of the

subject, mention should be made of the gas which so generally accompanies the oil. It is often met with in the oil-regions when no oil is struck, producing "gas-wells;" and is also met with where no oil, or very little, is found, on the borders of the oil-districts. Many private residences and manufacturing establishments are heated and lighted by this gas; Fredonia, New York, has been lighted with it for years. The Newton gas-well, five miles south of Titusville, Pennsylvania, is 786 feet deep, and yielded 4,000,000 cubic feet per day, supplying light and fuel to a great number of dwellings and manufactories in Titusville. A rolling-mill near Pittsburg is run by gas brought from Butler County, a distance of about nineteen miles, and when it is not needed the gas is lighted, furnishing a jet of flame seventy feet high, which, with another jet from a neighboring mill, furnishes a grand spectacle at night.

This gas is the cause of spouting-wells. If a well is sunk into the top of a fissure containing oil and gas, the gas will first escape, and then the oil must be pumped out; but, if the well strikes in the oil, the pressure of the gas would first drive out the oil. If water also was present and the well struck the bottom of the fissure the heavier water would first escape, then the oil, and then the gas. Such a well, after standing a while would again yield oil on pumping, then perhaps water only, or water and oil, until it had had another rest. If the supply of gas is kept up by an open crevice, the well may continue to flow for some time. The pressure of neighboring water may also cause the oil to flow from a well. Generally the pumping-wells are pretty constant, although when a number of wells are bored near together they interfere with each other, and sometimes water poured down one well will appear in another, and this method has been pursued to bring rival well-owners to terms.

A few words may here be said about drilling wells and transporting the oil. The wells are drilled by means of drilling-tools like those used in sinking artesian wells, which are suspended by a cable, and operated by small steam-engines. The well is lined with wrought-iron tubing, screwed together in sections, and, to prevent water from flowing down the outside of the lining into the well, a water-packer is used, which is essentially a circular piece of leather with the edges cut and turned upward, so that the whole forms a cup about the tube, which is pressed tightly against the sides of the well by the weight of the column of water. It is much better than the old flaxseed bag. The oil is conveyed from the oil-district to the refineries and shipping-stations by means of wrought-iron pipes, two to four inches in diameter, which form a network throughout the entire country, and have an aggregate length of nearly 2,000 miles. One company carries the oil thirty-seven miles, in this way, from Butler County to the vicinity of Pittsburg.

Refining and Uses of Petroleum.—Crude petroleum contains

gases and volatile liquids giving off at ordinary temperatures gases, which form explosive mixtures with air; heavy oils, which injure its burning properties, but are useful as furnishing lubricators and paraffine; tarry and carbonaceous matters; sulphur and other compounds, which give an offensive odor when burned. It is therefore refined by distillation, to separate the useful products in a pure state. The general features of the process will be best illustrated by a practical example, and for this purpose we have selected the well-known refinery of Charles Pratt & Co., at Greenpoint, Long Island, manufacturers of Pratt's Astral Oil. This establishment has a capacity of 15,000 barrels weekly.

The crude oil, coming mostly from Pennsylvania, with a specific gravity of 46 to 48° Beaumé, is run into horizontal cylindrical stills of wrought-iron, heated by anthracite fires. Eight of these stills have a capacity of 600 barrels each, and there are eight smaller ones. From these stills pipes lead to large worms, cooled by running water, and connected with a series of small tanks, so that the products from each still can be separately collected, and the successive portions that come from the still can be kept apart, according to their specific gravity.

At about 160° Fahr. (70° C.) the gases begin to come off abundantly, and these are conducted from the lower end of the worms to heat the steam-boilers. At about 225° Fahr. (107° C.) gasoline, having a specific gravity of 85° B., begins to run from the worm; after an hour and a half, at a temperature of 325° Fahr. (163° C.) naphtha begins to run, with a density of 74° B., and continues for about three hours; at 350–400° Fahr. (177–200° C.) benzine, with a density of 62° B., begins and runs about one hour. For the remainder of the heat, about thirty hours, illuminating oil is collected, with a density of 48–50° B., and ending with a temperature of 750° Fahr. (398 C.). The residuum, having a density of 20° B., is drawn off and shipped in barrels to the paraffine and lubricating oil-works. Steam is then run into the still for nearly two hours to remove the gas, the man-hole is opened, and the coke scraped off to be used for fuel.

The results of this operation are about as follows:

Gasoline	3	per cent.
Naphtha	10	" "
Benzine	3	" "
Illuminating oil	75	" "
Residuum	4	" "
Coke and loss	5	" "
Total	100	

The residuum yields by subsequent treatment paraffine to the amount of about one per cent. of the crude petroleum.

The illuminating oil comes from the worm at a temperature of

about 80° Fahr. (49° C.) and is pumped from the receiving-tank into the agitator, an immense cylindrical tank of boiler-iron, holding 1,800 barrels (a smaller one holds 500), where it is cooled (if necessary) to 60° Fahr. by water run in at the top by sprinkling from a hose, and drawn off below. Forty-four gallons of strong commercial sulphuric acid being added for every 100 barrels of oil, the mixture is agitated by air pumped in through a pipe leading down through the oil to the bottom. This is done by an engine, and produces a very thorough mixture, during which the temperature rises, and when it reaches 70° Fahr. (21° C.) the operation is ended. Water is then played upon the top for about three hours, when caustic-soda lye of 20° B. is added, in the proportion of 500 gallons to 1,800 barrels of oil, thoroughly agitated with the oil, and then drawn off at the bottom after settling. The sulphuric acid purifies the oil partly by combining with, partly by breaking up, the injurious compounds, and the soda is added to neutralize the acid. Finally, the oil is again washed with water and drawn off into bleaching-pans, of which one has a capacity of 2,000 barrels, and two others of 750 each. Here the oil is left under a roof and exposed to diffused daylight four or five hours, to improve its color, and is then removed to the storage-tanks. It is possible to expose the oil too long in the bleachers, injuring its color. It is a curious fact, noticed in several refineries, that the oil, after removal to the agitator and before treatment with the acid, sometimes gives off spontaneously inflammable gas, which has been known to take fire during the cooling with water.

The gasolene is used for making gas. The naphtha and benzine destined for the market are kept separate, but sometimes they are further treated at the refinery, and are then run together, and sent to the naphtha-works with a density of 68° to 70° B. Here they are treated in iron stills of 200 to 600 barrels capacity, heated by coal. The vapors are condensed in a series of three worms, and the operation is so managed that the various products are obtained of the required density. These products are gasolene, of 90° (sometimes 97°), 88°, and 86° B.; naphtha, of 76° and 71°; benzine, of 65° and 62°. Most of the benzine shipped is of the latter density. The barrels used for shipping all of these products are coated inside with glue.

The residuum is either "cracked" in special stills (a process of which we shall have more to say hereafter) or it is sold to be worked up for lubricating oils and paraffine.

Mr. Joshua Merrill, manufacturing chemist of the Downer Kerosene Oil Company, has made several very important discoveries in the treatment of petroleum, and a short account of them has been given in a "Memoir on Petroleum Products," communicated to the Society of Arts, Massachusetts Institute of Technology, by S. D. Hayes, March 14, 1872, from which some facts are here selected:

Neutral lubricating oil, free from offensive odors and tastes, was

partly the result of an accident. The condenser of a still heated by direct fire and charged with 900 gallons of mixed heavy and light oils, became partially closed, and the pressure caused leakage at the bottom of the still. The fire was very gradually drawn, after 250 gallons of light oil had passed off. The next day the oil in the still was found to be light-yellow, nearly odorless, neutral, and dense; the light, odorous hydrocarbons having been removed, at this low temperature, without decomposing either the distillate or the oil in the still. Further experiments perfected the process, which is greatly aided by the admission of steam from an open pipe into the body of the still during distillation.

Mineral sperm-oil was the result of experiments by Messrs. J. and R. S. Merrill on burning heavy lubricating oil and paraffine in lamps, especially constructed for the purpose. The light was very good, but the liquid was too thick to ascend into the wick. To obviate this the oil was subjected to a partially destructive distillation, "cracking" it enough to render it mobile, but not volatile.

The manner in which the crude petroleum is treated to obtain these various products is briefly outlined here from Prof. Hayes's sketch: The crude oil is heated by steam in upright, wrought-iron cylinders, incased in wood, of 12,000 gallons capacity. About 15 per cent. of distillate passes off and is condensed in pipes surrounded by water, yielding gasolene and A, B, and C naphthas, which are separately collected. From the gasolene rhigolene can be obtained by a second distillation with steam-heat, condensing the first portions of the distillate by ice and salt; ten per cent. is obtained from the gasolene. The steamed oil is pumped from the naphtha-stills into small stills, holding 1,000 gallons each, and heated by direct fires. Only carbon remains in these stills, some uncondensable gas escapes, and the other products are: No. 1, crude illuminating oil; No. 2, intermediate oils; No. 3, crude lubricating oil. Each of these is redistilled in the same sort of still. No. 1 is agitated with sulphuric acid, then with caustic soda, and distilled, yielding 80 per cent. of its volume of finished kerosene (refined illuminating oil) and mineral sperm-oil, and nearly 20 per cent. of denser oil. No. 2 is at once redistilled, yielding chiefly crude lubricating oil. No. 3 is agitated with sulphuric acid and then distilled with caustic soda in the still, yielding mainly dense paraffine-oil. This is kept in wooden barrels in ice-houses from seven to ten days, and deposits crystalline paraffine, which is pressed in strong cloth bags, one above another, with sheet-iron between, and yields crude paraffine-wax and heavy oil. The paraffine is repeatedly recrystallized from solution in naphtha and pressed, until it is white and pure enough for sale. The heavy oil is heated in stills by direct fires, slowly increased, but kept as low as possible, and generally with the admission of steam, until 20 to 30 per cent. has passed over. The residue is ready for sale,

having only a slight odor like that of fat-oils, while the hydrocarbons that are condensed after passing over have a very offensive odor. The very last distillates from all of the destructive distillations are called "cokings," and are distilled by themselves, yielding mainly crude lubricating oil. The carbon separated in the stills contains some caustic soda, which can be obtained as carbonate by burning the carbon and lixiviating the ashes. The sulphuric acid used in agitating the oils is known as "sludge," and is sometimes sold to the makers of superphosphate of lime, although it has been occasionally successfully reconverted into oil of vitriol. The following list includes the commercial products which have been made from petroleum, being those already mentioned, with the exception of cymogene, which is distilled from gasolene, and condensed by a pump:

1. *Cymogene*, specific gravity 110° Beaumé; boils at 32° F. (0° C.); used in ice-machines. 2. *Rhigolene*, sp. gr. 100° B.; boils at 65° F. (18.3° C.); extremely volatile, producing by its rapid evaporation a temperature of −19° F.; used as a local anæsthetic. 3. *Gasolene*, sp. gr. 97°, 90°, 88°, and 86° B., as required by the market. The very light gasolene is ordered in small quantities, probably for ice-machines. The others are used in gas-machines, for which they are admirably adapted, and for various exceedingly dangerous lamps and stoves designed for their combustion. 4. *Naphtha*, sp. g. 70° to 76° B.; boils at 180° F. (27 C.), when of 70° gravity; used in manufacture of oil-cloths, cleansing, as a solvent for paraffine, etc.; sometimes fraudulently mixed with the higher-priced illuminating oils, or with crude petroleum, to be again sold to the refiner; also sold, under various names, as a burning-fluid, notwithstanding the certain danger attending its use. 5. *Benzine*, sp. gr. 65° to 62° B.; the boiling-point for 65° B. is 300° F. (149° C.); used in making paints and varnishes. 9. *Illuminating oil* (*kerosene*), sp. gr. 45° to 50° B.; boiling-point for 45° B. is 350° F. (177° C.). "Astral" oil and "mineral sperm" are particularly safe varieties, freed with care from explosive compounds. 7. *Lubricating oil.* "Neutral" lubricating oil has a specific gravity of 29° B., and boils at 575° F. (301.5° C.). 8. *Paraffine*, sp. gr. 0.87°; fusing-point for commercial paraffine about 110° to 150° F. (43.3° to 65° C.), according to its purity; boiling-point about 698° F. (370° C.); used for making water-proof fabrics, candles, lubricators, matches, chewing-gum, etc.

The refined illuminating oil should be free from more volatile compounds, which cause it to give off vapors that explode when mixed with air and ignited. Dr. White, President of the New Orleans Board of Health, found that, on adding to oil which "flashed" at 113° F. one per cent. of naphtha, the mixture flashed at 103°; with two per cent. at 92°; with five per cent. at 83°; with 20 per cent. the oil itself burned at 50° ("Report on Petroleum to New York Board of Health," Dr. C. F. Chandler, 1871). Dr. Chandler has found that

the temperature of the oil in an ordinary glass oil-lamp ranges from 76 to 98° F., and in a metal lamp from 76° to 129° F., the lower limits being for rooms heated between 73° and 74° F., and the higher for a temperature of 90° to 92°. It is, therefore, evident that an oil giving off explosive gases at less than 100° F. must be dangerous, and even at 110° F. an accident might occur, but only in exceptional circumstances.

The oils must, therefore, stand a certain test, called the "flashing test," which consists in heating them, preferably, in a thin metal or glass cup which holds the oil, and is itself placed in another vessel full of cold water, which is gradually heated by a small spirit-lamp. The bulb of a thermometer is kept well immersed beneath the surface of the oil, draughts are to be avoided, and the heat very slowly raised. From time to time, as the flashing-point is approached, the temperature is noted, and a very small flame, as a gas-jet issuing from a glass tube drawn to a fine point, is quickly passed across its surface, taking care not to touch the oil. A faint blue flame will flash across the oil when it reaches a temperature at which explosive gases are given off. Although it is generally agreed that the temperature should be very gradually raised, fifteen minutes being allowed for a test, yet Calvert (*Chemical News*, May, 1870) states that an oil which flashed at 90° F., after fifteen minutes, showed a flashing-point of 101°, when thirty minutes were consumed in making the test. Oil of 100° is *not safe absolutely.* There is another test called the burning-test, the point at which an oil will take fire and burn; it is from 10° to 50° F. above the flashing-test (Chandler), and is of little value in determining the safety of an oil, because, as already shown, the addition of one per cent. of naphtha will lower the flashing-test 10° in a good oil, while it would not materially affect the burning-point. From the directions already given for testing oil any one can readily make the test, and in view of the large number of unsafe oils sold it is very important that such tests should be made before using an oil not known to be safe.

The subject of refining petroleum may be dismissed with a few words more about "cracking" oils. It is the object of the refiner to make as much illuminating oil as possible, and to do this advantage is taken of the fact that, when the vapors of heavy oils are heated above their boiling-points, carbon is deposited, and the condensed hydrocarbons resulting have a less specific gravity. This decomposition is technically called "cracking," and it was observed long ago that in distilling the heavier oils lighter hydrocarbons were obtained during the first stages of the operation, even when not wanted. Cracking can be accomplished by distilling the oils under pressure, or, as is the case in the very large stills now employed, by allowing the vapors of the heavier hydrocarbons, on condensing, to flow down again upon the now hotter oil in the still, whereby they are cracked, depositing carbon. By carefully adapting the heat to the changing

character of the oil, the yield of illuminating oil can be increased, but a residuum is always left in the large stills to be afterward treated in smaller ones.

S. D. Hayes states that this operation can be reversed, and from two to ten per cent. of a heavy oil obtained from the lightest and cheapest gasolene or petroleum naphtha. This change he observed in an apparatus constructed by Mr. Z. A. Willard, for generating gases and hydrocarbon vapors for metallurgical purposes. It consisted essentially of upright wrought-iron cylinders, half-full of the naphtha, through which steam at the ordinary working temperature and pressure passed, vaporizing the naphtha, and maintaining a pressure of about fifty pounds to the inch. The steam and naphtha vapors were thus kept above the liquid at a temperature much above the boiling-point of naphtha, but never as high as 300° Fahr., and the decompositions appeared to occur rather in the vapors than in the liquid. The heavy oil drawn off below had a dark yellowish-brown color, was nearly odorless after a few days' exposure to the air, had a specific gravity of about 34° Beaumé, and boiled above 400° Fahr. By redistilling, it was broken up into lighter and heavier liquid hydrocarbons, paraffine, and separated carbon (*American Journal of Science*, III., ii., 184).

Petroleum as a Fuel and Gas-Producer.—The use of gasolene in gas-machines is well known, and sometimes naphtha has been used to enrich coal-gas, by decomposing its vapor at a cherry-red heat, so as to produce a gas rich in heavy hydrocarbons, which is mixed with the coal-gas. Crude petroleum has also been conducted continuously into red-hot cast-iron retorts, whereby it is decomposed and rich gas formed. The Lowe process, now making daily 120,000 cubic feet of gas, of 19.5 candle-power, for a five-foot burner, at Utica, New York, is very successful. It consists essentially in forcing steam through a generator partly full of anthracite coal, brought to intense ignition; the steam is decomposed, and the resulting hydrogen meets crude petroleum that trickles down through the top of the generator; the petroleum is carried in vapor with the hydrogen into a "superheater" filled with loose fire-bricks, previously intensely heated by the gases from the generator. Here the hydrogen and hydrocarbons react upon each other, producing a permanent gas, which is purified as usual. The resulting gas is of uniform quality, very pure, and the saving in labor and materials is about 35 per cent. over coal-gas (*Scientific American*, January 8, 1876).

As regards the use of petroleum for fuel, it has always been found difficult to secure the complete combustion of the oil, so as to avoid smoke; the complicated nature of the contrivances devised for its use has also worked against its introduction as a fuel; but a furnace for reheating and rolling scrap-iron into boiler-plate has been invented by C. J. Eames, and is worked in Jersey City, which deserves mention. Prof. H. Wurtz (*American Chemist*, September, 1875) has de-

scribed it at length. A current of steam heated to incandescence, meeting crude petroleum as it drips slowly over cast-iron shelves, takes up all the oil and carries it to a chamber where it meets an air-blast and passes on to the combustion-chamber. This is a cellular tier of fire-bricks occupying the space over the bridge-wall of an ordinary furnace. Here the combustion begins, and thence the flames pass into the furnace, heating the six piles of iron, of 500 pounds each, which form a charge. Eight tons of boiler-plate can be worked off in ten hours with 300 gallons of crude petroleum, to which should be added 500 pounds of coal for generating and heating the steam. Petroleum is also used as a source of power in hydrocarbon engines (G. B. Brayton's), its vapor being mixed with air and ignited.

PRODUCTION AND VALUE OF PETROLEUM AND ITS PRODUCTS.—When the first abundant supplies of petroleum were obtained, the demand for it as an illuminator was small, and it could be bought at the wells for ten cents a barrel, or was even allowed to run to waste (Wrigley), but as the consumption increased the price rose steadily, reaching, in 1864, $13.75 per barrel. The average prices per barrel at Titusville are given below, taken from *Stowell's Petroleum Reporter*, Pittsburg:

1864	$7 62	1870	$3 74
1865	6 18	1871	4 50
1866	3 78	1872	3 84
1867	2 54	1873	1 84
1868	3 95	1874	1 29
1869	5 48	1875	1 48

The production of the Pennsylvania oil-region, from 1859 to 1874, according to Wrigley, has been as follows:

1859	3,200 barrels.	1867	3,347,306 barrels.
1860	650,000 "	1868	3,715,741 "
1861	2,113,600 "	1869	4,215,000 "
1862	3,056,606 "	1870	5,659,000 "
1863	2,611,359 "	1871	5,795,000 "
1864	2,116,182 "	1872	6,539,103 "
1865	3,497,712 "	1873	9,879,303 "
1866	3,597,527 "	1874	10,910,303 "

The yield for 1859 is put at about 2,000 barrels by Mr. S. H. Stowell, who has also kindly furnished the following statistics:

Total Yield of the United States in 1875.

Pennsylvania	8,787,506	bbls., of 42 galls.	
Western Virginia (approximated)	182,000	"	" "
All other sources, "	17,150	"	" "
Total	8,986,656	"	" "

The total value of the crude oils at the wells, up to the end of 1874, is given by Wrigley as $235,475,120, with an additional value for

the refining of 75 per cent. of the whole, at $2 per barrel, of over $100,000,000. The stock of crude oil on hand at the wells, in December, 1875, was 3,550,207 barrels. The total export from the United States during 1875 was: Crude petroleum, 378,532 barrels (of 40 gallons each); refined, 5,086,785; naphtha, 344,978. The average price of these in New York has been, per gallon:

	Crude, in Bulk.	Refined, in Barrels.	Naphtha, in Barrels.
1875.....	6.59 cents.	12.99 cents.	9.67 cents.
1874.....	5.86 "	13.09 "	8.85 "
1873.....	7.62 "	18.21 "	11.07 "
1872.....	12.80 "	23.75 "	14.81 "

Estimating the freight at $2.50 per barrel to the sea-board, and including the cost of refining and handling, Wrigley puts the total value of petroleum exported to foreign parts from Pennsylvania, since the beginning of the industry, at a minimum of $260,000,000.

In 1874 nearly 600 wells were drilled, producing an average of 50 barrels each; in 1875, about the same number, with an average of less than 25 barrels; and there were 3,125 producing-wells in Pennsylvania, January 1, 1876 (Stowell).

According to the rules of the New York Produce Exchange, crude petroleum shall be understood to be pure, natural oil, neither steamed nor treated, and free from water, sediment, or any adulteration, and of the gravity of 40° to 47° Beaumé. An allowance of one-half of one per cent. for every quarter of a degree above 47° gravity shall be made to the buyer. Refined petroleum shall be standard white or better, with a fire-test of 110° Fahr. or upward. Settlements of contracts shall be as follows: Barreled oil or naphtha, on a basis of forty-six gallons per barrel; refined oil, in bulk, forty-five gallons; crude oil, in bulk, forty gallons.

Dr. Chandler states that the average cost per hour of light equal to eight candles is as follows—the gas being sixteen-candle power, with a five-foot burner, the standard kerosene flashing at 115° Fahr., and the sperm-candles burning each 120 grains per hour:

From sperm-candles, at 42 cents per pound.....	5.76 cents.
Gas, at $3 per 1,000 feet.....	0.75 "
Mineral sperm-oil, in German student-lamp, at 75 cents per gallon..	0.57 "
" " in Merrill's lamp.....	0.48 "
Astral oil, in flat-wick lamp, at 50 cents per gallon.....	0.46 "
" " in German student-lamp.....	0.44 "
" " in Merrill's lamp	0.34 "
Standard kerosene, in flat-wick lamp, at 40 cents per gallon.....	0.33 "
" " in German student-lamp	0.31 "
" " in Merrill's lamp	0.28 "

LESSONS IN ELECTRICITY.[1]

HOLIDAY LECTURES AT THE ROYAL INSTITUTION.

By Prof. TYNDALL, F. R. S.

III.

SECTION 18. *Electric Induction.*—We have now to apply the theory of electric fluids to the important subject of electric *induction.*

It was noticed by early observers that *contact* was not necessary to electrical excitement. Otto von Guericke, as we have already seen, found that a body brought near his sulphur globe became electrical. By bringing his excited glass tube near one end of a conductor, Stephen Gray attracted light bodies at the other end. He also obtained attraction through the human body. From the human body, also, Du Fay, to his astonishment, obtained a spark. Canton, in 1753, suspended pith-balls by thread, and, holding an excited glass tube at a considerable distance, caused them to diverge. On removing the tube the balls fell together, no permanent charge being imparted to them. Such phenomena were further studied and developed by Wilcke and Æpinus, Coulomb and Poisson.

These and all similar results are embraced by the law that, when an electrified body is brought near an unelectrified one, the neutral fluid of the latter is decomposed, one of its constituents being attracted, the other repelled. When the electrified body is withdrawn, the separated electricities flow again together and render the body unelectric.

This decomposition of the neutral fluid by the mere presence of an electrified body is called *induction.* It is also called electrification by *influence.*

If, while it is under the influence of the electrified body, the body influenced be touched, the free electricity (which is always of the same kind as that of the influencing body) passes away, the opposite electricity being held captive.

On removing the electrified body the captive electricity is set free, the conductor being charged with electricity opposite in kind to that of the body which electrified it.

You cannot do better here than repeat Stephen Gray's experiment. Support a small plank upon a warm tumbler, and bring under one of its ends and near it scraps of light paper or of gold-leaf. Excite your glass tube vigorously, and bring it over the other end of the plank, without touching it. The ends may be six or eight feet apart; the light bodies will be attracted. The experiment is easily made, and you are not to rest satisfied till you can make it with ease and certainty.

[1] A course of six lectures, with simple experiments in frictional electricity, before juvenile audiences during the Christmas holidays.

This is a fit place to say that you must keep a close eye upon the tumblers you employ for insulation. Some of them, made of common glass, are hardly to be accounted insulators at all. We shall prove this.

Our mastery over this subject of induction must be complete, for it underlies all our subsequent inquiries. Without reference to it nothing is to be explained; possessed of it you will enjoy, not only a wonderful power of explanation, but of prediction. We will attack it, therefore, with the determination to exhaust it.

And here a slight addition must be made to our apparatus. We must be in a condition to take samples of electricity, and to convey them, with the view of testing them, from place to place. For this purpose the little "carrier," shown in Fig. 10, will be found convenient. *T* is a bit of tin-foil, two or three inches square. A straw stem is stuck on to it by sealing-wax, the lower end of the stem being covered by sealing-wax. To make the insulation sure, the part between *R* and *S'* is wholly of sealing-wax. You can have stems of ebonite, which are stronger, for a few pence; but you can have this one for a fraction of a penny. The end *R'* is to be held in the hand; the electrified body is to be touched by *T*, and the electricity conveyed to an electroscope to be tested.

Fig. 10.

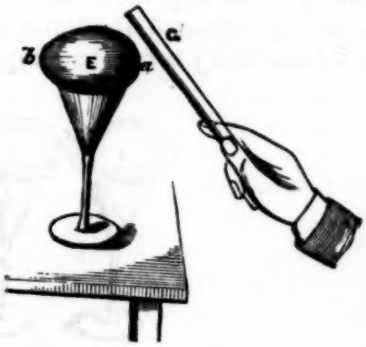


Fig. 11.

Touch your rubbed glass rod with *T*, and then touch your electroscope: the leaves diverge with positive electricity. Touch your rubbed gutta-percha or sealing-wax with *T*, and then touch your electroscope: the leaves diverge with negative electricity. If the electricity of any body augment the divergence produced by the glass, the electricity of that body is positive. If it augment the divergence produced by the gutta-percha, the electricity is negative. And now we are ready for further work.

Place an egg, *E*, Fig. 11, on its side upon a dry wineglass; bring your excited glass tube, *G*, within an inch or so of the end of the egg. What is the condition of the egg? Its electricity is decomposed; the negative covering the end *a* adjacent to the tube, the positive covering the other end *b*. Remove the glass tube: what occurs? The two electricities flow together and neutrality is restored. Prove this neutrality. Neither a carrier touching the egg, nor the egg itself, has any power to affect your electroscope, or to attract a lath balanced in the manner already described.

Again, bring the excited tube near the egg. Touch its distant part *b* with your carrier. The carrier now attracts the straw or the balanced lath. It also causes the leaves of your electroscope to diverge. What is the *quality* of the electricity? It repels and is repelled by rubbed glass; the electricity at *b* is, therefore, positive. Discharge the carrier by touching it, and bring it into contact with the end *a* of the egg nearest to the glass tube. The electricity you take away repels and is repelled by gutta-percha. It is, therefore, negative. Test the quality, also, by the electroscope.

While the tube *G* is near the egg touch the end *b* with your finger; now try to charge the carrier by touching *b:* you cannot do so —the positive electricity has disappeared. Has the negative disappeared also. No. Remove the glass tube, and once more touch the egg at *b* with the carrier. It is charged, not with positive, but with negative electricity. Clearly understand this experiment. The neutral electricity of the egg is first decomposed into negative and positive; the former attracted, the latter repelled by the excited glass. The repelled electricity is free to escape, and it has escaped on your

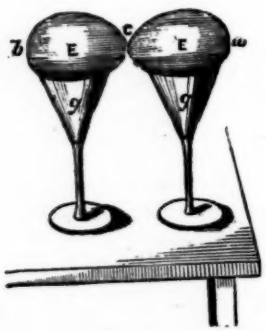


FIG. 12.

touching the egg with your finger. But the attracted electricity cannot escape as long as the influencing tube is held near. On removing the tube which holds the negative fluid in bondage, that fluid immediately diffuses itself over the whole egg. An apple, or a turnip, will answer for these experiments at least as well as an egg.

Discharge the egg by touching it. Reëxcite the glass tube and bring it again near. Touch the egg with a wire or with your finger at *a*. Is it the negative at *a*, into which you plunge your finger, that escapes? No such thing. The free positive fluid passes through the negative, and through your finger to the earth. Prove this, by removing first your finger and then the glass tube. The egg is charged negatively.

Again: place two eggs, *E E*, Fig. 12, lengthwise on two dry wineglasses, *g g*, and cause two of their ends to touch each other, as at *C*. Bring your rubbed glass rod near the end *a*, and while it is there separate the eggs by moving one glass away from the other. Withdraw the rod and test both eggs: *a* is negative, *b* is positive. The two charges neutralize each other in the electroscope. Again: bring the eggs together and restore the rubbed tube to its place near *a*. Touch *a* and then separate the eggs. Remove the glass rod and test the eggs: *a* is negative, *b* is neutral. Its electricity has escaped through the finger, though placed at *a*.

Push your experiments still farther, and, instead of bringing the eggs, *T' T''*, Fig. 13, together, place them six feet or so apart, and let a light chain, *C*, or wire stretch from one to the other. Two brass

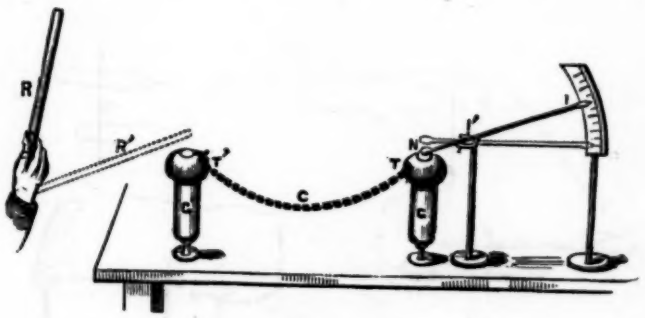


Fig. 13.

balls or wooden balls covered with tin-foil, and supported by tall drinking-glasses, *G G'*, will be better than the eggs for this experiment, for they will bear better the strain of the chain; but you can make the experiment with the eggs, or very readily with two apples or two turnips. For the present we will suppose the straw-index *I I'* not to be there. Rub your glass tube *R*, and bring it near one of the balls; test both: the near one, *T''*, is negative, the distant one, *T'*, positive. Touch the near one, the positive electricity, which had been driven along the chain to the remotest part of the system, returns along the chain, passes through the negative which is held captive by the tube, and escapes to the earth. When the tube is removed, negative electricity overspreads both chain and balls.

In Fig. 6 you made the acquaintance of the plate *N*, and the

straw-index *I I'*, shown in Fig. 13. By its means you immediately see both the effect of the first induction and the consequence of touching any part of the system with the finger. The plate *N* rests over the ball or turnip *T*, the position of the straw-index being that shown by the dots. Bring the rubbed tube near *T'*: the end *N* of the index immediately descends and the other end rises along the graduated scale. Remove the glass rod; the index *I I'* immediately falls. Practise this approach and withdrawal, and observe how promptly the index declares the induction and recomposition of the fluids.

While the tube is near *T*, and the end *N* of the index is attracted, let *T''* be touched by the finger. The end *N* is immediately liberated, for the electricity which pulled it down escapes along the chain and through the finger to the earth. Now remove your excited tube. The captive negative electricity diffuses itself over both balls, and the index is again attracted.

Instead of the chain you may interpose between the balls one hundred feet of wire supported by silk loops. This is done in Fig. 14, which shows the wire *w* supported by the silk strings *S S S*, and where, for the ball or turnip, the cylinder *C*, on a glass support *G*, is substituted. Every approach and withdrawal of the rubbed glass tube *R* is followed obediently by the corresponding motion of the index.

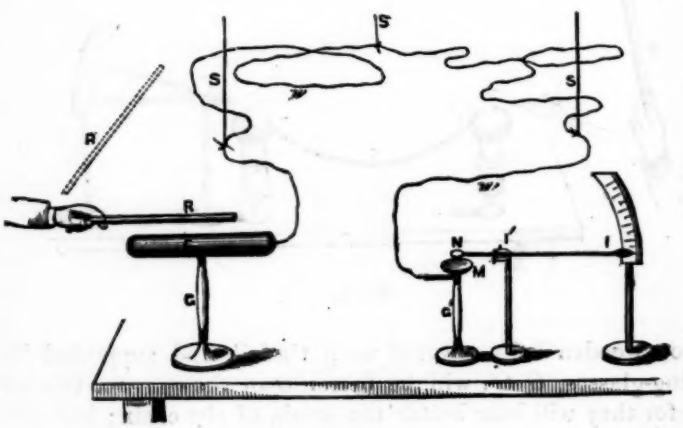


FIG. 14.

Or, substituting a carrot, a cucumber, or other elongated conductor for the ball *T'*, Fig. 12, you cause your rubbed glass tube to act upon a greater extent of surface. You thus decompose more electricity and produce a greater attraction.

Repeat here an experiment, first made by a great electrician named Æpinus. I wish you to make these grand old experiments. Support an elongated metal conductor, or one formed of wood coated with tin-foil—even a carrot, cucumber, or parsnip, so that it will be insu-

lated, will answer. Let a small weight suspended from a silk string rest on one end of the conductor, and hold your rubbed glass rod near the other end. You can predict beforehand what will occur when you remove the weight. It carries away with it electricity, which repels rubbed glass, and which attracts your balanced lath.

Stand on an insulating stool: make one, if necessary, by placing a board on four warm tumblers. Present the knuckles of your right hand to the end of the balanced lath, and stretch forth your left arm. There is no attraction. But let a friend or an assistant bring the rubbed glass tube over the left arm; the lath immediately follows the right hand.

While matters continue thus, touch the lath, which I suppose to be uninsulated; the "attractive virtue," as it was called by Gray, disappears. After this, as long as the excited tube is held over the arm there is no attraction. But when the tube is removed the attractive power of the hand is restored. Here, you will at once comprehend, the first attraction was by positive electricity driven to the right hand from the left, and the second attraction by negative electricity, liberated by the removal of the glass rod.

Stand on an insulating stool, and place your right hand on the electroscope: there is no action. Stretch forth the left arm and permit an assistant alternately to bring near, and to withdraw, an excited glass tube. The gold-leaves open and collapse in similar alternation. At every approach, positive electricity is driven over the gold-leaves; at every withdrawal, the equilibrium is restored.

I will now ask you to charge your Dutch gold electroscope positively by rubbed gutta-percha, and to charge it negatively by rubbed glass. A moment's reflection will enable you to do it. You bring your excited body near: the same electricity as that of the excited body is driven over the leaves, and they diverge by repulsion. Touch the electroscope, the leaves collapse. Withdraw your finger, and withdraw afterward the excited body: the leaves then diverge with the opposite electricity.

The simplest way of testing the quality of electricity is to charge the electroscope with electricity of a known kind. If, on the *approach* of the body to be tested, the leaves diverge still wider, the leaves and the body are similarly electrified. The reason is obvious.

The wealth of knowledge, and of interest, which these experiments involve, may be placed within any boy's reach by the wise expenditure of half a crown.

Once firmly possessed of the principle of induction and versed in its application, the difficulties of our subject will melt away before us. In fact, our subsequent work will consist mainly in unraveling phenomena by the aid of this principle.

Without a knowledge of this principle we could render no account

of the attraction of neutral bodies by our excited tubes. In reality, the attracted bodies are *not* neutral: they are first electrified by influence, and it is because they are thus electrified that they are attracted.

This is the place to stamp upon your mind the following considerations: Neutral bodies, as just stated, are attracted, because they are really converted into electrified bodies by induction. Suppose a body to be feebly electrified positively, and that you bring your rubbed glass-rod to bear upon the body. You clearly see that the induced negative electricity may be strong enough to mask and overcome the weak positive charge possessed by the body. We should thus have two bodies electrified alike, attracting each other. This is the danger against which I promised to warn you in Section 10, where the test of attraction was rejected.

We will now apply the principle to explain a very beautiful invention, made known by the celebrated Volta in 1775.

Sec. 14. *The Electrophorus.*—Cut a circle, T (Fig. 15), six inches in diameter, out of sheet-zinc, or out of common tin. Heat it at its

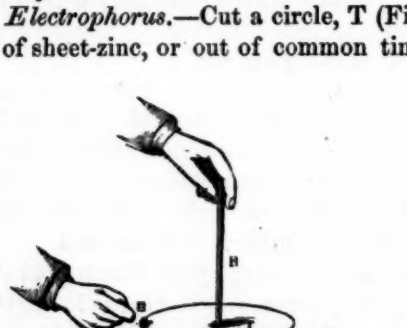


Fig. 15.

centre by the flame of a spirit-lamp or of a candle. Attach to it there a stick of sealing-wax, H, which, when the metal cools, is to serve as an insulating handle. You have now the lid of the electrophorus. A resinous surface, or what is simpler a sheet of vulcanized India-rubber, P, or even of hot brown paper, will answer for the *plate* of the electrophorus.

Rub your "plate" with flannel, or whisk it briskly with a fox's brush. It is thereby negatively electrified. Place the "lid" of your electrophorus on the excited surface: it touches it at a few points only. For the most part lid and plate are separated by a film of air.

The excited surface acts by induction across this film upon the lid, attracting its positive and repelling its negative electricity. You have in fact in the lid two layers of electricity, the lower one, which is "bound," positive; the upper one, which is "free," negative. Lift

the lid: the electricities flow again together; neutrality is restored, and your lid fails to attract your balanced lath.

Once more place the lid upon the excited surface: touch it with the finger. What occurs? You ought to know. The free electricity, which is negative, will escape through your body to the earth, leaving the chained positive behind.

Now lift the lid by the handle: what is its condition? Again I say you ought to know. It is covered with free positive electricity. If it be presented to the lath it will strongly attract it; if it be presented to the knuckle it will yield a spark.

A smooth half-crown or penny will answer for this experiment. Stick to the coin an inch of sealing-wax as an insulating handle; bring it down upon the excited India-rubber: touch it, lift it, and present it to your lath. The lath may be six or eight feet long, three inches wide, and half an inch thick; the little electrophorus-lid, formed by the half-crown, will pull it round and round. The experiment is a very impressive one.

Scrutinize your instrument still further. Let the end of a thin wire rest upon the lid of your electrophorus, under a little weight if necessary, and connect the other end of the wire with the electroscope. As you lower the lid down toward the excited plate of the electrophorus, what must occur? The power of prevision now belongs to you and you must exercise it. The repelled electricity will flow over the leaves of the electroscope, causing them to diverge. Lift the lid, they collapse. Lower and raise the lid several times, and observe the corresponding rhythmic action of the electroscope-leaves.

A little knob of sealing-wax, *B*, coated with tin-foil; or indeed any knob with a conducting surface, stuck into the lid of the electrophorus, will enable you to obtain a better spark. The reason of this will immediately appear.

Sec. 15. *Action of Points and Flames.*—The course of exposition proceeds naturally from the electrophorus to the electrical machine. But before we take up the machine we must make our minds clear regarding the manner in which electricity diffuses itself over conductors, and more especially over elongated and pointed conductors.

Rub your glass tube and draw it over an insulated sphere of metal —of wood covered with tin-foil, or indeed any other insulated spherical conductor. Repeat the process several times, so as to impart a good charge to the sphere. Touch the charged sphere with your carrier, and transfer the charge to the electroscope. Note the divergence of the leaves. Discharge the electroscope, and repeat the experiment, touching, however, some other point of the sphere. The electroscope shows the same amount of divergence. Even when the greatest exactness of the most practised experimenter is brought into play, the spherical conductor is found to be equally charged at all points of its surface. You may figure the electric fluid as

a little ocean encompassing the sphere, and of the same depth everywhere.

But supposing the conductor, instead of being a sphere, to be a cube, an elongated cylinder, a cone, or a disk. The depth, or as it is sometimes called the *density* of the electricity, will not be everywhere the same. The corners of the cube will impart a stronger charge to your carrier than the sides. The end of the cylinder will impart a stronger charge than its middle. The edge of the disk will impart a stronger charge than its flat surface. The apex or point of the cone will impart a stronger charge than its curved surface or its base.

You can satisfy yourself of the truth of all this in a rough but certain way, by charging, after the sphere, a turnip cut into the form of a cube; or a cigar-box coated with tin-foil; a metal cylinder, or a wooden one coated with tin-foil; a disk of tin or of sheet-zinc; a carrot or parsnip with its natural shape improved so as to make it a sharp cone. You will find the charge imparted to the carrier by the sharp corners and points, to be greater than that communicated by gently-rounded or flat surfaces. The difference may not be great, but it will be distinct. Indeed, the egg laid on its side, as we have already used it in our experiments on induction, yields a stronger charge from its ends than from its middle.

Let me place before you an example of this distribution, taken from the excellent work on "Frictional Electricity," by Prof. Riess, of Berlin, who is probably the greatest living exponent of the subject. Two cones, Fig. 16, are placed together base to base. Calling

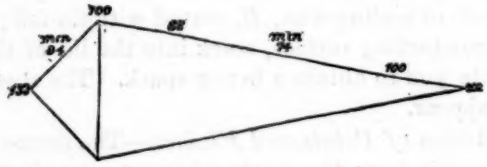


Fig. 16.

the strength of the charge along the circular edge where the two bases join each other 100, the charge at the apex of the blunter cone is 133, and at the apex of the sharper one 202. The other numbers give the charges taken from the points where they are placed. Fig. 17, moreover, represents a cube with a cone placed upon it. The charge on the face of the cube being 1, the charges at the corners of the cube and at the apex of the cone are given by the other numbers; they are all far in excess of the electricity on the flat surface.

Riess found that he could deduce with great accuracy the *sharpness* of a point, from the charge which it imparted. He compared in this way the sharpness of various thorns with that of a fine English sewing-needle. The following is the result: Euphorbia-thorn was sharper than the needle; gooseberry-thorn of the same sharpness as

the needle; while cactus, blackthorn, and rose, fell more and more behind the needle in sharpness. Calling, for example, the charge obtained from euphorbia 90, that obtained from the needle was 80, and from the rose only 53.

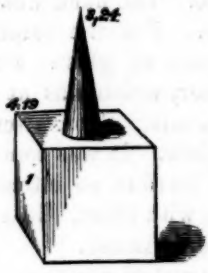


FIG. 17.

Considering that the electricity is self-repulsive, and that it heaps itself up upon a point in the manner here shown, you will have little difficulty in conceiving that, when the charge of a conductor carrying a point is sufficiently strong, the electricity will finally disperse itself by streaming from the point.

The following experiments are theoretically important: Attach a stick of sealing-wax to a small plate of tin, so that the stick may stand upright. Heat a needle and insert it into the top of the stick of wax; on this needle mount a carrot. You have thus an insulated conductor. Stick into your carrot at one of its ends a sewing-needle, and hold for an instant your rubbed glass rod in front of this needle without touching it. What occurs? The negative electricity of the carrot is discharged from the point against the glass rod. Remove the rod, test the carrot: it is positively electrified.

And now for another experiment, not so easily made, but still certain to succeed if you are careful. Excite your glass rod, turn your needle away from it, and bring the rod near the other end of the carrot. What occurs? The positive electricity is now repelled to the point, from which it will stream into the air. Remove the rod and test the carrot: it is negatively electrified.

Again, turn the point toward you, and place in front of it a plate of dry glass, wax, resin, shellac, paraffine, gutta-percha, or any other insulator. Pass your rubbed glass tube once downward or upward, the insulating plate being between the excited tube and the point. The point will discharge against the insulating plate, which on trial will be found negatively electrified. These experiments, I may say, were discussed, and differently interpreted by the two philosophers, during an important correspondence between Faraday and Prof. Riess.[1]

[1] "*Philosophical Magazine*," vol. xi., 1856.

SEC. 16. *The Electrical Machine.*—An electrical machine consists of two principal parts: the insulator which is excited by friction, and the "prime conductor."

The sulphur sphere of Otto von Guericke was, as already stated, the first electrical machine. The hand was the rubber, and indeed it long continued to be so. For the sulphur sphere Hauksbee and Winckler substituted globes of glass. Boze, of Wittenberg (1741), added the prime conductor, which was at first a tin tube supported by resin, or suspended by silk. Soon afterward Gordon substituted a glass cylinder for the globe. It was sometimes mounted vertically, sometimes horizontally. Gordon so intensified his discharges as to be able to kill small birds with them. In 1760 Planta introduced the plate machine now commonly in use.

Mr. Cottrell has constructed for these lessons the small cylinder machine shown in Fig. 18. The glass cylinder is about seven inches long and four inches in diameter; its cost is eighteen pence. Through the cylinder passes tightly, as an axis, a piece of lath, rendered secure

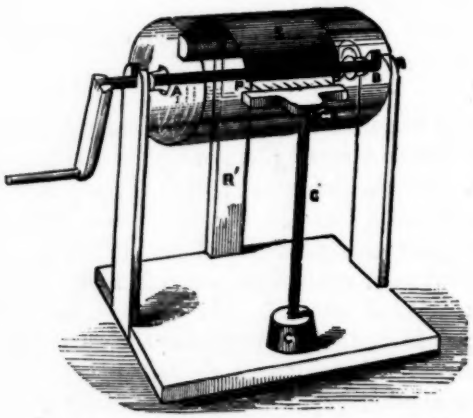


FIG. 18.

by sealing-wax where it enters and quits the cylinder. *G* is a glass rod supporting the conductor *C*, which is a piece of lath coated with tin-foil. Into the lath is driven the series of pin-points, *P*, *P*. The rubber, *R*, is seen at the farther side of the cylinder, supported by the upright lath, *R'*, and caused to press against the glass. *S'* is a flap of silk. When the handle is turned sparks may be taken, or a Leyden-jar charged at the knob *C*. A plate machine is shown in Fig. 19. *P* is the plate; *R* and *R'*, two rubbers which clasp the plate. *A* and *A'* are rows of points presented by the conductor, *C*. *C C'* is an insulating rod of glass, intended to cut off the connection between the conductor and the handle of the machine.

The prime conductor is thus charged: when the glass plate is

turned, as it passes each rubber it is positively electrified. Facing the electrified glass is the row of points midway between the two rubbers. On these points the electrified glass acts by induction, attracting the negative and repelling the positive. In accordance with the principles already explained the negative electricity streams from the points against the excited glass, which passes on neutralized to the next rubber, where it is again excited. Thus the prime conductor is charged, not by the direct communication to it of positive electricity, but by depriving it of its negative.

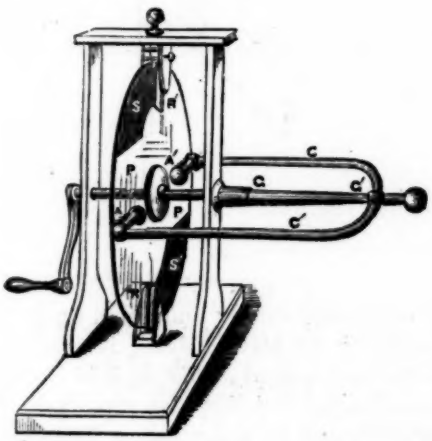


FIG. 19.

If, when the prime conductor is charged, you bring the knuckle near it, the electricity passes from the conductor to the knuckle in the form of a spark.

Take this spark while the machine is being turned, and then try the effect of presenting the finger-ends, instead of the knuckle, to the conductor. The spark falls exceedingly in brilliancy. Substitute for the finger-ends a needle-point, you fail to get a spark at all. To obtain a good spark the electricity upon the prime conductor must reach a sufficient density (or tension, as it is sometimes called). To secure this, no points from which the electricity can stream must exist on the conductor, or be presented to it. All parts of the conductor are therefore carefully rounded off, sharp points and edges being avoided.

It is usual to attach to the conductor an electroscope, consisting of an upright metal stem, *A C*, Fig. 20, to which a straw with a pith-ball, *B*, at its free end, is attached. The straw turns loosely upon a pivot at *C*. The electricity passing from the conductor is diffused over the whole electroscope, and the straw and stem, being both positively electrified, repel each other. The straw, being the movable body, flies away. The amount of the divergence is measured upon a graduated arc.

If no point exist on the conductor, a single turn of the handle of the machine suffices to cause the straw to stand out nearly at right angles to the stem. If, on the contrary, a point be attached to the conductor, you cannot produce a large divergence. The reason is, that the electricity, as fast as it is generated, is dispersed by the point. The same effect is observed when you present a point to the

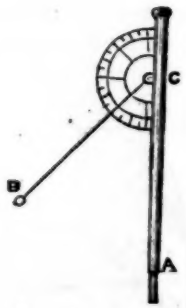


FIG. 20.

conductor. The conductor acts by induction upon the point, causing the negative electricity to stream from it against the conductor, which is thus neutralized almost as fast as it is charged. Flames and glowing embers act like points; they also rapidly discharge electricity.

The electricity escaping from a point or flame into the air renders the air self-repulsive. The consequence is that, when the hand is placed over a point mounted on the prime conductor of a machine in good action, a cold blast is distinctly felt. Dr. Watson noticed this blast from a flame placed on an electrified conductor, while Wilson noticed the blast from a point. Jallabert and the Abbé Nollet also observed and described the influence of points and flames. The blast is called the "electric wind." Wilson moved bodies by its action; Faraday caused it to depress the surface of a liquid; Hamilton employed the *reaction* of the electric wind to make pointed wires rotate. The "wind" was also found to promote evaporation.

Hamilton's apparatus is called the "electric mill." Make one for yourself thus: Place two straws $S\,S$, $S'\,S'$, Fig. 21, about eight inches long, across each other at a right angle. Stick them together at their centres by a bit of sealing-wax. Pass a fine wire through each straw and bend it where it issues from the straw, so as to form a little pointed arm perpendicular to the straw, and from half an inch to three-quarters of an inch long. It is easy, by means of a bit of cork or sealing-wax, to fix the wire so that the little bent arms shall point not upward or downward, but sideways, when the cross is horizontal. The points of sewing-needles may also be employed for the bent arms. A little bit of straw is stuck into the cross at the centre, to form a cap. This slips over a sewing-needle, N, supported by a stick of

sealing-wax, *A*. Connect the sewing-needle with the machine, and turn. A wind of a certain force is discharged from every point, and the cross is urged round with the same force in the opposite direction.

You might easily, of course, so arrange the points that the wind from some of them would neutralize the wind from others. But the little pointed arms are to be so bent that the reaction in every case shall not oppose, but add itself to, the others.

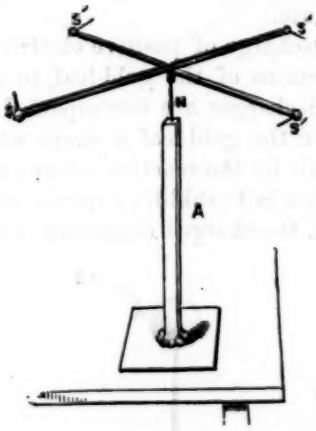


FIG. 21.

The following experiments will yield you important information regarding the action of points: Stand, as you have so often done before, upon a board supported by four warm tumblers. Hold a small sewing-needle, with its point defended by the forefinger of your right hand, toward your Dutch metal electroscope. Place your left hand on the prime conductor of your machine. Let the handle be turned by a friend or an assistant: the leaves of the electroscope open out a little. Uncover the needle-point by the removal of your finger: the leaves at once fly violently apart.

Mount a stout wire upright on the conductor of your machine; or support the wire by sealing-wax, gutta-percha, or glass, at a distance from the conductor. Connect both by a fine wire. Bend your stout wire into a hook, and hang from it a tassel composed of many strips of light paper. Work the machine. Electricity from the conductor flows over the tassel, and the strips diverge. Hold your closed fist toward the tassel, the strips of paper stretch toward it. Hold the needle, defended by the finger, toward the tassel: atctration also ensues. Uncover the needle without moving the hand; the strips retreat as if blown away by a wind.

And now repeat Du Fay's experiment which led to the discovery of two electricities. Excite your glass tube, and hold it in readiness, while a friend, or an assistant, liberates a real gold or silver leaf in

the air. Bring the tube near the leaf: it plunges toward the tube, stops suddenly, and then flies away. You may chase it round the room for hours without permitting it to reach the ground. The leaf is first acted upon inductively by the tube. It is powerfully attracted for a moment, and rushes toward the tube. But from its thin edges and corners the negative electricity streams forth, leaving the leaf positively electrified. Repulsion then sets in, because tube and leaf are electrified alike. The retreat of the tassel in the last experiment is due to a similar cause.

There is also a discharge of positive electricity into the air from the more distant portions of the gold-leaf, to which that electricity is repelled. Both discharges are accompanied by an electric wind. It is possible to give the gold-leaf a shape which shall enable it to float securely in the air by the reaction of the two winds issuing from its opposite ends. This is Franklin's experiment of the Golden Fish. It was first made with the charged conductor of the electrical machine.

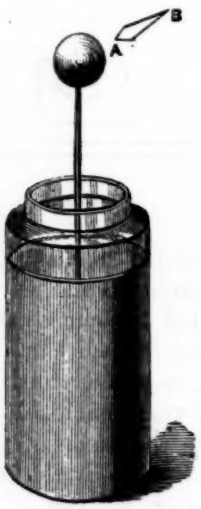


FIG. 22

M. Srtsczek revived it in a more convenient form, using instead of the conductor the knob of a charged Leyden-jar. You may walk round a room with the jar in your hand; the "fish" will obediently follow in the air an inch or two, or even three inches, from the knob. (*See A B*, Fig. 22.) Even a hasty motion of the jar will not shake it away.

Well-pointed lightning-conductors, when acted on by a thunder-cloud, behave in the same way. The opposite electricity streams out from them against the cloud.

Franklin saw this with great clearness, and illustrated it with great ingenuity. The under-side of a thunder-cloud, when viewed

horizontally, he observed to be ragged, composed of fragments one below the other, sometimes reaching near the earth. These he regarded as so many stepping-stones which assist in conducting the stroke of the cloud. To represent these by experiment, he took two or three locks of fine loose cotton, tied them in a row, and hung them from his prime conductor. When this was excited, the locks stretched downward toward the earth; but, by presenting a sharp point erect under the lowest bunch of cotton, it shrunk upward to that above it, nor did the shrinking cease till all the locks had retreated to the prime conductor itself. "May not," says Franklin, "the small electrified clouds, whose equilibrium with the earth is so soon restored by the point, rise up to the main body, and by that means occasion so large a vacancy that the grand cloud cannot strike in that place?"

HINTS FOR THE SICK-ROOM.

WHEN a woman thinks of making deliberate choice of the profession of a sick-nurse, she can, of course, take into careful consideration if her character and temperament are or are not suited for so arduous and trying an avocation. If she is a person of excitable nature, and possessed of but little self-control, she can be wisely counseled to give up the idea of a life for which she is so thoroughly unfit; but no peculiarities of character or temperament can exempt a woman from being called upon by the plain voice of duty, at one time or other of her life, to take her stand by the bedside of one dear to her, and soothe as best she may many a weary hour of restlessness and pain.

Very few, indeed, are the women who escape this rule—most have to take upon themselves the burden of attendance in a sick-room—and perhaps there are few subjects upon which the generality of women are so well-intentioned, and yet so ignorant. With the very best and kindest meaning in the world, attention bestowed upon a suffering person may be productive of more discomfort than comfort to the patient, and endless annoyance to the physician, just because the zealous, but alas! untrained and undisciplined volunteer does everything the wrong way.

Again, from a mistaken and unreal idea of true delicacy and refinement, many women shrink from ever seeing or learning anything about suffering or sorrow; and so, when the inevitable fate brings the sights and sounds of pain, the dreadful realities of death, cruelly home to them, they are paralyzed by terror, and useless, nay, worse than useless to those most dear to them. Even as I write, sad instances rise before my mind of a lack of moral courage, an utter im-

possibility of self-command, that has led the mother to flee from the bedside of her dying child, the wife to turn away from the failing sight that yearns to gaze upon her face while life yet lingers! The contemplation of pain could not be borne, because the mind was weakened and enervated by a selfish habit of yielding to the dislike of bravely facing anything disagreeable. Let all true women train themselves to possess self-control, calmness, and patient courage; let them strive to acquire a certain amount of knowledge of the cares and duties of the sick-room; let them not shrink from hearing the details of this or that form of suffering and disease, and gladly and readily offer help (when they rightly and safely can) outside the bounds of their own immediate home circle. Let them rejoice in any fitting opportunity that may come in their way of perfecting themselves in this, the highest and holiest of woman's duties, so that when their own time of trial comes they may not fail!

Taking it for granted that there are many who will gladly take a few plain and practical hints on this subject, I shall condense the result of a somewhat long and wide experience into a short space.

And, first: It is in things which of themselves appear trifling, and even insignificant, that the comfort of a sick-room is made or marred. For instance, an energetic and amiably-intentioned person places a cold pillow beneath the shoulders of a patient suffering from pneumonia, that is, inflammation of the lungs; a fit of coughing, perhaps a restless night, is the result. Five minutes' warming of the pillow at the fire would have prevented all this mischief, and even conduced to sleep.

Dress, again, is a matter of great importance in a sick-room, and here I must enter a protest against that very common practice of the amateur sick-nurse making a "guy" of herself. I really have seen such startling and unpleasant costumes donned "for the occasion," as seemed to me enough to cause delirium in the patient, if long contemplated—shawls, and dressing-gowns, and wraps, of such an obsolete and awful character, that the shadow of the watcher, cast upon the wall by the dim light of the night-lamp, must form a horrible "old granny," and be by no means a *pleasing reflection* to meet a sick man's eyes, as he wakes weak and confused from an opiate-won sleep!

The best dress for a sick-room is plain black—for the simple reason that no stain shows upon it—an old silk is the most economical, but silk rustles, and is therefore objectionable. Black lustre is very serviceable—not made long enough to trail, upset chairs, and get under the doctor's feet; and not having hanging sleeves, but fitting close and neat at the wrist, so as to be finished off by nice white linen cuffs. (I have seen a hanging sleeve catch on some projecting point of chair or table, and convert a glass of egg-flip into a "douche" externally applied, swamping the patient in a yellow sea, besides send-

ing her into hysterics.) A habit of moving quietly about the room, and yet not treading "on tiptoe" and making every board in the floor creak its loudest, is also very advisable; and nothing can be better by way of foot-gear than those soft, warm felt boots now so common; they both keep the nurse's feet from becoming cold, and make the least possible sound in moving about. Of course the manner of speaking in a sick-room is all-important. Oh, the horror of that dreadful "pig's whisper," which penetrates to the inmost recesses of the room, and wakes the sleeping patient as surely as the banging of a door!

I call to mind a case of fever—a very bad case, in which sleep was the one desideratum—almost the only hope. The sufferer had fallen into a doze—the terrible throbbing of the arteries in the bared throat seemed a little less rapid—the fire that was burning life away raged a little less fiercely—but, some idiot peeped in through a half-closed door, and with horrible contortions of the visage, intended to express extreme caution, whispered in blood-chilling tones, "How—is—he—getting—on—now?"

In an instant the patient had raised himself in bed, the poor hot hands were thrown out to ward off he knew not what—the filmy eyes stared wildly round—the parched tongue faltered: "What is it? Where is it?" And for hours the weary head tossed from side to side, and meaningless words fell on the ears of those who watched and waited, and almost feared to hope. And yet it was meant in kindness!

In some of the most severe diseases, such as cholera and diphtheria, the patient is often *intensely* conscious of all that is passing around him. The wish to know everything that is said and done is extreme, and nothing excites a patient so much as anything like whispering and mystery. The natural voice, only so much lowered as to be perfectly distinct, is, then, the proper tone for a sick-room. If silence is needed, let it be complete, and no whispering permitted either in the room, or, worse still, outside the door.

And now I must say a few words on a disagreeable but yet most important subject. In any case where operative surgery is necessary, it cannot be too strongly insisted upon that no one shall remain present whose calmness and self-control are not a certainty. I remember well a delicate and difficult operation having to be performed—not a painful one, but where success mainly depended on the perfect stillness of the patient. Scarcely had the first slight incision been made, when the room resounded with the moans and cries, not of the sufferer, but the friend who had kindly come to support her through the ordeal! With many a sob, and choke, and gurgle, the friend was assisted from the room, and then all went well enough; but great delay, and much increase of nervousness on the part of the patient, naturally resulted.

One of the many very eminent surgeons of whom America can boast once told me that on the occasion of performing a most formidable operation, in which promptitude was a vital necessity, he saw, at a moment when seconds were precious, a friend, who had insisted on remaining present, suddenly turn deadly pale, and fall fainting on the floor, in uncomfortably close proximity to the chloroformed patient. Dr. B—— stooped down, and quietly rolled the insensible individual into a corner of the room, where he enjoyed undisturbed repose until such time as some one had time to "bring him to."

Thus it may be seen that any one who is in the least nervous, and cannot be certain of his own powers of self-command, acts with truer kindness in remaining absent from such scenes, than by becoming an added source of anxiety, where there is so much already of the gravest character. If, however, a woman has the moral courage to face such trials calmly, and without flurry—if she can do simply what she is told, and *nothing more*—if she can hold her tongue—wholly dismiss herself from her own mind, concentrating all her attention on the patient, she may be of untold help and comfort. On the other hand, a sick-nurse who asks the doctor endless questions—who presumes in her ignorance to criticise his treatment—who is spasmodic in her sympathy, and ejaculatory in her lamentations, is pestilent in a sick-room, and should, if possible, be got rid of at any cost.

But as well as the nervous and excitable nurse, there is another species of the genus against whom I would warn any one who in the least values his own comfort, and that is, the person who insists upon "helping you" to nurse some very severe case, and never ceases assuring you that she "keeps up splendidly at the time, but afterward—;" and then comes an ominous shake of the head, which is a ghastly intimation of what a time you will have of it with her, when what she is pleased to call the "reaction" sets in. Nothing can be more aggravating than to contemplate such an individual, and look forward to the "breaking-down" which she assures you is inevitable, and which you feel assured will come just when you and everybody else are tired out with nursing the real sufferer, and when you want to go to bed, and sleep your sleep out. The very idea of having to put hot-water bottles to her feet, and mustard-poultices to her side, and cooling lotions to her aching brow, and watch her acting the martyr (the while you are wishing her at Jericho, or some other equally hard-to-get-back-from place), is not a pleasant anticipation, as you sit opposite to her through a long night of watching, and she tells you, with a melancholy yet vainglorious countenance, how she shall "pay for this afterward." But she treats with scorn your suggestion that she should go to bed—indeed, she would be bitterly disappointed if she might not immolate herself—and you. This sort of thing is what I call "selfish unselfishness," a kind of self-sacrifice that is always acting as its own bill-poster.

But there is one kind of nervousness which I do not think meets with sufficient consideration, and that is the unconquerable fear which you will find some people have of any disease that is infectious. Now, I think this sort of fear is far more constitutional than mental, and it appears to me most uncharitable to speak of those who are thus nervous by temperament as "so frightened," etc. Depend upon it, if any one has a great dread of infection, he is far better away from the chance of it. If I heard a person express a great and overpowering dread of small-pox, cholera, fever, or diphtheria, I should do all in my power to prevent that person going near any case of the kind, because I should be morally certain of the result. As a rule, I believe that those who are perfectly fearless are comparatively safe; and there is no truer test of perfect freedom from nervous dread than the fact of being able to sleep at once, quietly and naturally, and without the mind being obliged to dwell upon the work of the day. The best cholera-nurse I ever saw used to tell me that she often sat down in the corner of a room, on the floor, and "slept right off" for half an hour at a time, either day or night, just as such opportunity for rest presented itself. But of course there are exceptions to all rules; and one of the most devoted and the most fearless in attendance on the sick, during a terrible epidemic, died just when the worst of the battle seemed over.

But to return to some of those "trifles," the knowledge of which is so needful to those who would try to fulfill well the duties of an amateur sick-nurse.

When active personal care of a sick person is undertaken, the finger-nails should be kept very short. I have seen a long nail tear open a blister, and expose a raw surface, causing great pain. For the same reason, all removable rings should be taken off; and any ornaments that hang loose and make a jingling noise are best dispensed with, as they irritate and annoy a sensitive patient.

It seems to me that this very unpretending paper will be hardly complete without a few words as to the diet that is best for any one acting as sick-nurse in a long and trying case.

One great point is, to let no silly notions of sentiment prevent you making a practice of taking substantial and regular meals; and, when you have to sit up all night, be sure and have food at hand, and never go more than three hours without eating. Now, I am going to say what I know many will highly disapprove of, and it is this: when you are nursing a long and anxious case, and you want to be able to "stay" to the end, *avoid all stimulants.* There is nothing you can do such hard work upon, there is nothing that will support you in long-continued watching and fatigue, like good, well-made coffee. Stimulants only give a temporary excitement, that passes itself off as strength. They injure that clearness of thought, that perfect quietude and recollectedness which are so essential to the good sick-nurse;

and they tend more than anything else to that miserable "breaking-down afterward" of which I have already spoken.—*Chambers's Journal.*

THE POLAR GLACIERS.

By C. C. MERRIMAN.

II.

THE element of all others most sensitive to the changes and impulses of every kind of force is the earth's atmosphere. It is in a state of constant disturbance, and seems to be obedient to no laws or regularity. Yet, unstable as the winds appear, they are really, in their general movements, among the most orderly and effective agents in Nature. This is shown in a remarkable manner by their agency in impelling the great ocean-streams, and therefore their important influence on glacial phenomena. In order to make this evident, it will be necessary to explain in brief the general laws of their circulation.

The earth turns on its axis from west to east, and with it rotates daily the enormous envelope of the atmosphere. The velocity of rotation at the equator is something over 1,000 miles an hour; at thirty degrees distance it is about 150 miles an hour less. In higher latitudes it is still less; and at the poles nothing. Therefore, whenever the air moves north or south on the surface of the earth, it will carry with it a less or greater velocity of rotation than the places it passes over, and will turn into an easterly or westerly wind, according as it approaches or recedes from the equator. In the region of the sun's greatest heat, the air, rarefied and lightened, is continually rising, and cooler currents come in on both sides to take the place of the ascending volume. As these side-currents come from a distance of about thirty degrees from the equator, they have, at starting, an eastward velocity many miles an hour less than the localities they will eventually reach. Consequently they will appear to lag behind in all the course of their progress to the equator—that is, they will have a westerly motion united with their north and south movements. These are the great trade-winds, blowing constantly from the northeast on this side, and the southeast on the other side of the equator.

But the heated air, which has risen in immense volumes in the tropics, spreads out to the north and the south in the upper regions, passes entirely over the trade-winds, and comes down to the earth in the temperate zones. It, however, continues to have the velocity toward the east which it acquired at the equator, and, when it strikes the slower-moving latitudes, it will be traveling much faster than the regions it comes down upon. Hence the westerly winds that prevail almost constantly in the middle latitudes.

This is the normal order of the wind-currents, and that which would prevail with nearly perfect regularity if the world were a uniform globe of water or of land, and equally heated on both sides of the equator. But the continents, and particularly mountain elevations, produce great disturbances—unequal rainfalls and ever-varying atmospheric pressures. When also, from any cause, one of the trade-winds, notably the southern, is increased in its violence, so as to push a tornado-tongue across the dividing line, into the opposite system of winds, there is started one of those cyclones, or great circular storms, which ravage the tropics and whirl through the temperate zones, finally exhausting themselves in the higher latitudes to the eastward.

The southern hemisphere is at the present time colder than the northern, owing primarily to the fact that the winters there are eight days longer than the northern, and the sun, during those seasons, about 3,000,000 miles farther from the earth than during the northern winters. The difference of temperature, therefore, between the warm air that rises at the equator and the cold air that comes in from the south is greater than that on the north side. And, as it is difference of temperature that produces the whole movement of the air-currents, of course the greater strength of that movement must be on the southern side. Hence the larger share of the equatorial current passes over to the south, and the southern trades are much the strongest. In accordance with this theory, it is a matter of observation that the southern trade-winds reach across the equator and into the northern hemisphere in some places ten to fifteen degrees.

In obedience to and perfect accord with this great system of winds, the waters of the oceans move. The strong southeast trades blow up from Southern Africa, cross the equator, and drive the waters of the South Atlantic into the Caribbean Sea. The lighter northeast trades, blowing between North Africa and the West Indies, assist and give direction to this movement, which finally impels through the Straits of Florida a tide of tropical waters a hundred times greater than the outflow of all the rivers in the world. This great flood of thermal waters spreads out in the Northern Atlantic, imparting to Europe a climate corresponding to countries twenty degrees south of it on this side of the ocean. There is, of course, an under-current from the Arctics to the equator, exactly compensating this enormous northward flow of the surface-waters. The same process and effect are repeated in the Pacific Ocean; and the great Japan Stream robs the southern hemisphere, for the benefit of our Pacific States, only in a degree less than does the Gulf Stream for the benefit of Europe.

A change in the relative strength of the trade-winds, such that the northeast trades would blow across the equator into the southern hemisphere, would entirely reverse the course of the warm ocean-currents, and carry to the southern continents the heat abstracted from the northern. Such a change in the course of ocean-streams has

unquestionably followed every change in the glaciation of the hemispheres from astronomical causes. The winds and the water-currents have always helped to increase the difference in temperature which a considerable eccentricity of the earth's orbit must always have produced between the northern and southern halves of our globe. It matters but little which of the two—the ocean-currents or the astronomical causes—have produced the greater effect, since it is certain that they have ever coöperated in one and the same direction.

On all the tropical seas, between the terminal lines of the two trade-winds, there is what is called the belt of calms, a tract averaging from 300 to 500 miles wide, in which, whatever winds there may be, are exceedingly light and unreliable. It is here, as we have seen, that the air and vapor, heated by the vertical rays of the sun, are continually rising and spreading outward in the upper regions. It is a complete dividing line between the climates of the two hemispheres. One may be frigidly cold, while the other is highly heated; the only difference being that the calm belt would be removed farther into the warmer hemisphere. It now ranges from five to ten degrees of latitude on this side of the equator. In this belt of ascending air-currents is carried up the greater part of the moisture which afterward descends as rain or snow far from the equator. Whatever excess of solar heat there may be on the tropics is here absorbed in evaporating water. To vaporize a pound of water, according to Prof. Tyndall, requires as much heat as to raise fifty-five pounds of ice-water to the boiling-point. It is manifest, therefore, that there must have been, during the glacial periods, an enormous amount of sun-power somewhere on the face of the earth to have supplied the vapor that buried one zone and half of another beneath a solid ocean of ice.

These facts effectually do away with all the theories, except the astronomical, which have been advanced by physicists to account for glacial phenomena: one, that our solar system has, during certain ages, passed through a colder region of space; another, that the sun in glacial times for some cause failed to supply his usual quantity of heat; and, as a consequence of either, that the glaciation of both hemispheres occurred at the same time. Equatorial heat is as necessary to a glacial period as polar cold. The one transforms the waters to vapor and elevates it to the cloud-spheres, while the other sends in the cold winds beneath, which compel the vapors to come over to the frozen side and build up the glacier.

The system of the stratified rocks has been called the great geological book, with its uncounted leaves overlying each other. Now, as it is a part of the glacial theory that each of these leaves or strata, at least in greater part, was the work of a glacial period, it is important for us to examine closely and particularly the course and effect of one of these great cycles of 21,000 years or thereabouts. We will take, for example, that one of the Post-tertiary glacial which

was of the greatest extent and severity. Ten cycles back—about 210,000 years ago—one of the periods of maximum eccentricity had just commenced, the highest since four times that number of years. The perigee, or nearest approach to the sun, happened then as now, a few days after the winter solstice of our half of the world. It was the great summer of the northern hemisphere. But over the southern hemisphere at this time, almost if not quite to the tropics, extended one vast sheet of ice. It reached far into Brazil, it covered Southern Africa, and lapped over on Australia. The marks are all there, scored on the solid rocks, to show how it crept up the southern slopes of the hills, and how far it pushed its icy arms. In South America at least there is ample proof that the great glacier spanned the southern ocean to reach it; for the furrows on the rock-beds of Patagonia are from the pole toward the equator, whereas in any other case they would have been from the mountains to the sea. With such a state of things at the southern end of the world, with probably miles in depth of ice and sea in its higher latitudes, there could have been but little water left for the opposite northern regions. What is called the Atlantic-cable plateau, between Newfoundland and Ireland, was very possibly the north shore of the Atlantic Ocean; and probably no considerable bodies of water existed anywhere north of that parallel. The present continents were all mountain tablelands, far from the vicinity of evaporating surfaces. Like all such elevated regions not exposed to specially moist winds, they were doubtless dry and arid deserts. However warm may have been the climate of the north temperate and arctic zones during this their great summer, their great elevation and the want of any kind of water-supply must have made them barren of all forms of animal or vegetable life. Consequently there would be, as is notably the case, but few if any traces of this part of the great season left in the geological records, at least above the present seas.

Five thousand years pass, and the perigee has advanced to meet the vernal equinox. The spring season is now the shortest of all; but, as the autumnal is correspondingly lengthened, the average climate is about that of the present time. But it is the season of the great thaw—the breaking-up time—of the southern hemisphere, and the waters are returning to fill the northern ocean-beds. Imperceptibly a permanent white cap begins to fasten itself to the heights of the boreal zone, to extend its outline, and to increase its depth. Slowly the lands are being submerged and the oceans broaden out, till there comes a time when land and water are equalized in the two hemispheres, and the climates are substantially alike.

Another 5,000 years pass, and the perigee now coincides with the summer solstice of the northern hemisphere. This is the position there of greatest cold: the winters are twenty-eight days longer than the summers; and the extra days are in great part those

of the briefest sunshine. Besides this, the earth is 10,500,000 miles farther from the sun in winter than in summer. According to the most careful calculations, the temperature of extreme northern regions would be lowered 50°, and the mean annual range would be fully 60° below zero. This in all probability would carry the isothermal line of Labrador, South Greenland, and Iceland (32° Fahr.), down to Charleston and the Gulf of Mexico. The late Prof. Agassiz found ice-marks as far south as this, though it can hardly be supposed that the permanent glacier extended so far. There are, however, abundant signs of the permanent ice-layer all over the State of New York, and both east and west of it. The same distinguished authority was wont to claim in his lectures that all the beautiful north and south lakes of Western New York—the Cayuga, the Seneca, the Canandaigua—were ploughed out of the solid rock and walled around with their clay and gravel hills by advancing and retreating glaciers. The rocky summits of New England are found to be grooved and scored all over their sides and tops with markings always in nearly a north and south direction. They have been traced on Mount Washington to within 300 feet of the highest point. There can be no doubt that at the time we are writing of, about 200,000 years ago, there was one solid ice-stratum of immense thickness—Agassiz said from two to three miles—slowly being pushed from the northward by the power of freezing water, over all of New England and the lake States.

Again the perigee proceeds to meet the autumnal equinox. The winter and the summer seasons have again become equal in length; and the sun is just half its time on the north side of the equator. The great ice-shroud is now being gradually withdrawn. Where it abuts on deep waters, enormous icebergs are broken off and float away to the south, carrying bowlders and soil and whatever it may have picked up in its slow course down to the sea. Where it terminates in shallow waters or on the land, its effect is to produce such an arrangement and diversity of soils and such a peculiar outline of country as no other agency could ever have brought about. So different is the nature and work of the great polar glacier from anything with which we are familiar at the present day, that it has seemed to me to require a few words of more particular description.

As is well known, the glacier is an accumulation of many winters' snows consolidated by pressure into a clear blue ice. In this condition it manifests the peculiar property of viscous bodies—it is in continual slow motion in the direction of least resistance. Whether it is by the expansion produced by the repeated thawing and freezing of water in its interstices, as Agassiz claimed, or whether by the pressure of the mass and glacial regelation, which is the constant freezing together of ice-surfaces in contact, after breaking under unequal pressures, or crushing against obstacles, which is the theory of Prof. Tyndall, or whether by both causes combined, certain it is that large

bodies of ice not only flow like a heavy lava-stream, conforming themselves to all inequalities of the surface, but they also scrape along in solid mass, as if pushed by some irresistible force from behind. Mountain-glaciers show both motions. But the great polar glacier, extending over comparatively level surfaces, seems to have been pushed bodily outward from its fixed polar base, and to have moved almost entirely under the mighty impulse of expansion. The parallel scratches and furrows which, in our hemisphere, mount straight up the north sides of mountains; the worn and rounded appearance of those sides and of the summits, as compared with the rough, unsmoothed southern slopes; the erratic blocks, or some peculiar specimens like the native copper of Lake Superior, carried almost directly south for scores or hundreds of miles, over heights, and even over arms of the sea—all show conclusively that the great glacier pushed its meridional course over all obstacles and to long distances.

Imbedding in its under surface the grit and gravel on which it froze, this mountain grindstone grated and ground the solid rocks over which it passed into the various materials of soil. Sand and gravel were the products from granitic rocks and sandstones, clay from the slates and shales, and loam from the softer lime-rocks. But the most striking effects which the polar glacier produced were the long ridges of gravel and bowlder-clay hills which it scraped up as it advanced, and left at the end of its journey, or at each halting-place of its retreat. For it must be borne in mind that the glacier was still pushing southward all the time that it was, on the whole, retreating. These terminal moraines are either the promiscuous gatherings of clay and bowlders and earths of all kinds, or, if they have been subjected to the sorting influence of moving waters, they are gravel hills with sandy bases, and clay flats extending usually to the southward of them. They run in somewhat parallel courses easterly and westerly, sometimes hundreds of miles. Great numbers of these concentric ridges may be counted in Western New York, between the long Lake Ontario ridge and the lake hills of the south part of the State. Several cross the New England States, one running along the coast of Maine, and westerly through the White Mountains. In addition to these are the lateral moraines, running in an opposite direction. These were, some of them, pushed out at the sides by outstretching arms of the glacier; others were formed by streams running down through breaks or fiords in the melting ice-sheet. So extensive and so marked are the traces of the great polar glacier over all middle latitudes, both north and south, that it may truly be called the great landscape-gardener of the temperate zones.

But it is natural to conclude that, if there has been one glacial era caused by astronomical cycles, there must also have been others in earlier geological times. And, as we turn back the pages of the great earth-book, we find therein recorded the evidences of the vicissitudes

of climate which we thus anticipate, but, if we mistake not, in continually-lessening force and extent the farther back we go. For, long ages previous to the recent glacial epoch, through all the Tertiary era, the fossil plants and animals indicate the prevalence of a warm and genial climate over the greater part of the globe. Then come the chalk-beds of the Cretaceous period, in which are frequently found water-worn blocks of granite and aggregations of pebbles, proving that then, as now, the iceberg floated down from the north over seas that were quietly depositing the chalk-shells. Still older is found a long series of secondary strata, the Oölite, the Lias, and the Trias, which were deposited in at least sub-tropical climates. They are the burial-grounds of the enormous saurian reptiles that once had an age all to themselves in the world's chronology. Their remains have been found within a thousand miles of the north-pole, thus proving that warm seas covered every zone.

Between the great divisions of Secondary and Primary in geology, there lies a stratum found only in the higher half of the latitudes, and known as the Permian or New Red Sandstone. The scanty life-forms found in it, and the coarse grit and angular bowlders of which it is composed, evince the well-known glacial action. Geologists generally think that there elapsed between these great divisions a very long period of time in which, excepting the sandstone, but little was done one way or another to build up the crust of the earth or leave a mark in its records. This doubtless indicates periods of very small eccentricity. Such periods did occur, according to Mr. Croll's calculations, immediately before and after the great eccentricity of 850,000 years ago, in which we may perhaps conjecture the New Red Sandstone to have been formed.

Previous to this age were the long Carboniferous periods, during all of which a warm and moist climate prevailed over all lands that have yet been explored. Below the coal-measures are found again the grits and bowldery conglomerates of the Old Red Sandstone, which, with great paucity of organic remains, would imply the alternations of somewhat glacial climates. The Silurian, Cambrian, and Laurentian systems preceded the Old Red in the order named, and reach back to the dawn of life on the earth. These formations are of vast thickness, and were deposited at the bottom of warm seas in all parts of the world.

It cannot be denied that, as we go back in the geologic records, we find more and more the evidences of greater heat and a more equable climate. It is certain that the astronomical relations which we have pointed out—the revolutions of the orbital points and the alternations of great and small eccentricity—have never ceased to exist. Therefore, if the world had been subjected to only the same solar heat in ancient as in recent periods, there must have been repeated glacial epochs; and we should find the bowlder, and the un-

sorted drift, and the scratched and polished rocks, all through the stone presentations. But very few, if any, such evidences have been found.

Again, for a warm and exuberant climate to extend into the arctic zone, there was necessary one of those great summers of considerable eccentricity, without the excessive drainage, which an unusually large accumulation of ice in the opposite hemisphere would necessitate. Each summer cycle of coal forests, or of reptile monsters, implies, not only a long visit, and a high evaporating power of the sun, but also the addition, to the opposite polar regions, of a weight of ice only sufficient to draw the waters from a small part of the low and flat lands of the warmer hemisphere. We have seen that periods of warm, perhaps even tropical climates in polar latitudes, intervened between the great winters of the last glacial epoch. But they have left scarcely a trace in the strata. They were the nearest approach possible, with the sun-power of recent times, to the conditions which of old brought out such a profusion of animal and vegetable life. But the only result in the later periods was, that the earth was unbalanced. All the waters were either turned into ice, or were following after it toward one of the poles. One side of the world was a frozen waste, while the other was a burning waste.

I think we cannot avoid the conclusion that the sun shone with a far intenser power on the Carboniferous swamps and the Oölitic shoals than on the gravel-hills of the Drift; that the oceans of early times were wider and warmer than now, and circulated more freely between the tropics and the polar seas; and that the heated and moisture-laden atmosphere retained the heat and equalized the temperature between the equator and the poles far more than at present.

With these conditions, that is, with a greater sun-power and a considerable eccentricity of the earth's orbit, I can conceive a rational explanation, that which I have not yet seen in the books, of the formation of the coal-layers, alternated as they always are with marine deposits. These alternations are sometimes very numerous. There are as many as sixty distinct veins of considerable thickness, one over another, in the coal-mines of South Wales, as also of Nova Scotia. There must have been, in that case, sixty periods of dry land, each of sufficient duration to grow many forests, and each followed by a long-continued submergence, in order that each layer should become fossilized, and buried beneath a shale or a limestone, which could only have formed in the depths of a quiet sea. The books say there were so many upheavals, and a like number of subsidences, alternating with each other. As if Old Earth had bent her back, for her load of pit-coal, threescore times among the Welsh hills, and again as many more at Halifax. It is a far more reasonable explanation, that each considerable layer of coal indicates a cycle of long summers, and the withdrawal of a moderate depth of the oceans from one hemisphere to the other, by reason of moderate accumulations of ice in

polar latitudes, and the return, again, of the waters after 10,500 years. In this way, and in no other that I can conceive of, can be fairly explained the constant mixture and alternations of terrestrial and marine relics, all through the fossil-bearing formations, and the hundreds, if not thousands of different and distinct strata which are found lying one above another.

Whoever, even cursorily, studies the phenomena of geology, must be impressed with the enormous length of time it has taken to arrange the terrestrial substructure, and prepare it for the higher forms of life. Even the comparatively recent period of the Bowlder Clay, which laid out the grounds of the present area of civilization, dates back for its commencement, as we have seen, probably 200,000 years. If it might be assumed that the Permian or New Red Sandstone was formed during the next previous period of extraordinary eccentricity, which was 850,000 years ago, then the Devonian or Old Red Sandstone would come in, very appropriately, at the next anterior era of extraordinary focal distance, which occurred 2,500,000 years back. The Carboniferous period, which came between these two, could not have been formed in less than 1,000,000 years, as most geologists concede; and by calculations previously indicated, those sixty Welsh layers of coal, if there are that many, divided off by marine deposits of considerable thickness, would have consumed 1,250,000 years.

The average thickness of all the strata that lie above the Old Red Sandstone is not far from two miles. But this formation is itself, in many places, two miles thick. And the lower Primary systems will add at least ten miles to the vertical measure of the fossil-bearing rocks. It is estimated that "the fossiliferous beds in Great Britain, as a whole, are more than 70,000 feet in thickness;" and many that are there wanting, or nearly so, elsewhere expand into beds of immense depth. There are certainly fifteen miles deep of strata to be accounted for—the slow accretions of the ages—mainly ocean-sediment that has come down from the wear and washings of the solid rocks. It would be by no means a bold assumption to say that 20,000,000 years had elapsed since the eozoön first built its reefs in the warm Laurentian seas.

AXES AND HATCHETS, ANCIENT AND MODERN.[1]

By the Rev. ARTHUR RIGG, M. A.

TOOLS with cutting-edges are not only numerous and varied in form, but they are also varied in the purposes for which they are formed, and in the mode of using. Hence no very precise statement of what is generally meant by a "cutting-edge" can well be

[1] From a lecture delivered before the London Society of Arts.

given. Three classes, however, of such tools may be marked out, and into one or other of these it is probable all those tools which can properly be defined as tools with cutting-edges may be arranged.

A first class will comprehend tools which meeting the work at a particular angle continue the path of each portion of the edge in the same straight line. Axes, adzes, gouges, chisels, and planes (as ordinarily used by carpenters), belong to this class. Such tools are brought into action either by impact or by direct thrust. The adaptation of machinery to tools in this class is easy, because the cutting-edge has to describe only a straight line, and this done once, if the place of application be removed, a repetition of impact or thrust in the same direction will suffice.

FIG. 1.—ADZE OF FLINT.

A second class will comprehend tools which, while as a rule retaining the angle at which they are applied to the work, the path of any portion of the tool is not a straight but a curved line. Tools of Class 2 are seldom acted upon by direct impact, or simple thrust. To adapt them to machine-work requires either a compound motion in the tool, or a motion compounded of the tool and work. When used as handicraft tools, this compound motion is derived from the muscular actions of the body of the workman, or the mechanical contrivances of construction in the tool. Knives, shears, razors, and saws, belong to this class. And to this class belong those tools in which what are mechanical contrivances for causing a "draw cut" are introduced, e. g., certain garden and pruning shears, also, hay and bread cutting knives. There is a motion in the human jaws which gives to the cutting teeth this "draw cut," and so they separate what is between them as draw-cut scissors might do. Indeed, all tools in this class operate most efficiently when acting upon the "draw-cut" system.

Hence, while certain of the human teeth belong to Class 1, others belong to Class 2. The contrivance in the jointing of the lower jaw to the upper in man is a compound one, adapting itself to three motions, one or other of which is found in many tools. There is up-

and-down motion, enabling certain of the teeth to cut meat as nippers do. There is also a backward-and-forward motion, producing a saw or file like operation, and there is a lateral or side motion, producing such a result as that of grinding. It is probable that, from observation on the action of the teeth, the "draw cut," so essential to the perfection of tools that really *cut*, has been suggested.

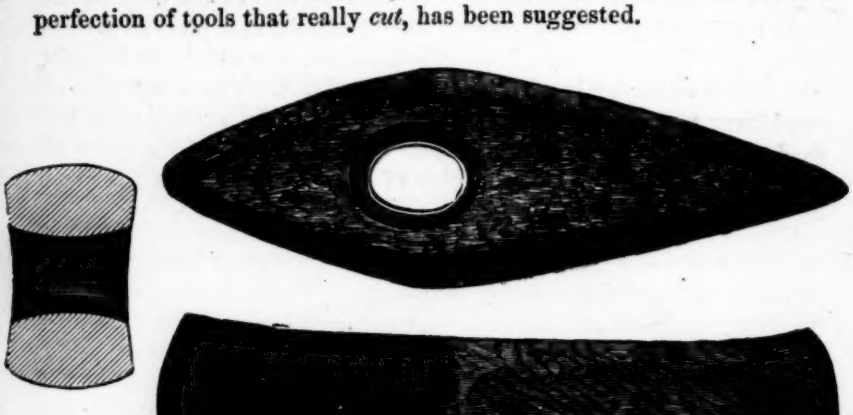


FIG. 2.—DOUBLE-EDGED AXE OF GREENSTONE.

Class 3 will comprehend those tools in which rotation is more usual than rectilineal motion. The tools in this class are constructed on principles allied to those in the two former classes. All drilling and boring tools belong to this class.

The action of tools with cutting-edges in Class 1, being the most simple, had better be first considered. As axes and adzes belong to this class, and as the structure of habitations probably led our ancestors to the formation of tools, doubtless that form of cutting-instrument which most commended itself to these primitive artificers would be the first to be constructed. Passing by the very early form, we may commence with a consideration of the edge of the axe or adze, when that edge became part of a constructed implement, and not a mere piece of sharp-edged flint. The construction essential to the tool is a handle, or, as it is called, a "helve." The shape of this helve, and the mode in which the head or metal of the axe is attached to it, are well worthy of some preliminary attention.

Perhaps here may be drawn the distinction between narrow and broad axes and hatchets. Axes are tools to be used with both hands; they have long handles, and may be swung as sledge-hammers. Hatchets are to be used with one hand, have short handles, they are much lighter and thinner than axes, and are employed more in the trimming than in the hewing of timber. Both narrow and broad axes are employed in forestry, the woodman's choice being affected by the

size of the timber and the character of the fibre. A hatchet is handled with the centre of gravity nearer the cutting-edge than the line of the handle; an axe with the centre of gravity in the line of handle produced. Of this, however, more hereafter.

The mode of attaching a handle to an axe in the bronze age is very instructive to us. The illustrations are suggestive enough, and need only a passing remark. It will be observed that for the purpose of handling, some of these axes are socketed, others wedge-pointed. The socketed ones were evidently handled as we handle socketed chisels. There is, however, one peculiarity, and that worthy of consideration. These bronze hatchets have in many instances a semicircular, ring-like projection (*see* Figs. 4 and 5), the object of which was for a long time a puzzle, but the suggested mode of handling the implements, if correct as seen in the diagram, points to a knowledge of directions of tension and of pressure, which engineers at the present day cannot but admire. If any one has ever struck a common hatchet to any great depth into timber, and carelessly endeavored to loosen it by raising the extremity of the handle, he may have found the handle separate from the metal near the junction of the two. Now the withe, or lashing, shown in this bronze instrument, has been put, as we should put it at the present day, in order to strengthen the connection at this, the weakest part.

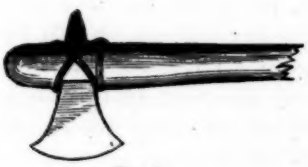


Fig. 3.

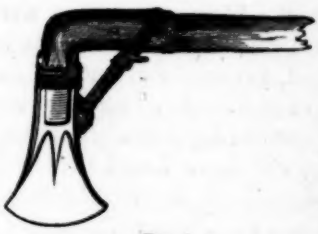


Fig. 4.

Fig. 5.

Figs. 3, 4, 5, are examples of the modes of handling these ancient bronze hatchets. Fig. 3 is the most primitive. Fig. 4 and Fig. 5 illustrate the mode adopted to strengthen by tension-cords the weakest part of the handle. A remnant of this tension-cord is probably

seen in the increased depth now given to the handle, where it enters the eye. It will be noticed that Fig. 5 is socketed as a carpenter's heavy mortising-chisel. The commendable pride of these prehistoric workmen in the beauty of their tools may be inferred from the ornamentation of these bronze axe-blades.

When we pass from the tool and its contrived handle to the mode of using, and the purpose for which it has been constructed, we find, as a rule, a cutting-edge formed by two inclined surfaces meeting at an angle, the bisecting line of which passes through the middle of the metal. It is very apparent that the more acute this angle is, the greater, under the same impact, will be the penetrative power of the axe into the material against which it is driven. This supposition very soon needs to be qualified, for suppose the material offers a great resistance to the entrance of this edge, then the effect of the blow, upon the principle that action and reaction are equal, will react upon the edge, and the weakest, either edge of axe or object struck, must yield. Here, then, primitive experience would be obliged to qualify the simple tool in which the edge was keen and acute, and would naturally sacrifice the keenness and acuteness to strength.

When early uses of the axe are considered, it will be noticed that, even in fashioning with an axe or adze the same piece of wood, different conditions of edge are requisite. If the blow be given in the direction of the fibre, resistance to entrance of the edge is much less than in the blow across that fibre. So great, indeed, may this difference become, that while the axe in Class 1 seems in all respects a suitable tool, yet as the attention of the workman passes to directions inclined to the fibre at an angle of more than forty-five degrees, he will be induced to lay aside the tools in Class 1, and try those in Class 2; for he will have found that while in the one direction of the wood the edge of his axe continues sound and efficient, yet a few blows on the same timber at right angles to this direction have seriously damaged the perfection of the edge, whatever may be the angle at which the faces meet which constitute the edge.

These remarks apply only to tools used in dividing materials, and not to tools used in preparation of surfaces of materials. This preliminary consideration prepares us for the different circumstances under which these two classes of tools may be respectively used. And as the contrast of the effect of the same tool under different circumstances in the same substance is considerable, great also is likely to be the contrast between the edges of the tools and the manner of using them, e. g., the axe, which is the proper tool in the direction of the fibre, is operated upon by impact, while a saw, which is the proper tool across the fibre, is operated upon by tension or thrust, but never by impact.

The mode in which the axe is used will explain why it is unsuited for work across the fibre. The axe is simply a wedge, and therefore

arranged to cleave, rather than to cut, the wood. Now, a calculation of the pressure necessary to thrust forward a wedge, and the impact necessary to cause the same wedge to enter the same depth, would explain why (regarded as a wedge only) the handle proves an important adjunct to the arm of the workman. Any one may test this by using an ordinary-handled hatchet on a soft straight-grained wood, or he may take a small axe with a straight and not a curved edge; let it rest upon a lump of moderately soft clay. Add weights until it has sunk to any decided depth, then take the axe by the head, and by pressure force the edge to the same depth. Next, hold the axe by the handle, first at, say, one foot from the head, then at two feet, then perhaps at three feet, and give blows which seem of equal intensity, and mark the depth. Thus a practical testimony to the value of a handle will be borne by the respective depths.

A few words about the motion of the hands and the handle they grasp; and then a consideration of the curves given to the cutting-edges of axes, adzes, etc.; also to the wedge-like sections of the edges. These will be all that can now be considered.

The motions of the hands on the handle of an axe are similar to those of a workman on that of the sledge-hammer. The handle of a properly-handled axe is curved, that of a sledge-hammer is straight. For present consideration this curvature may be overlooked, although it plays an important part in the using of an axe with success and ease. If the almost unconscious motions of a workman skilled in the use of an axe be observed, it will be noticed that, while the hand farthest from the axe-head grasps the handle at the same or nearly the same part, the other hand, or the one nearest to the head, frequently moves. Let us follow these motions and consider the effect of them. The axe has just been brought down with a blow and entered between the fibres of the wood. In this position it may be regarded as wedged in the wood, held in fact by the pressure of the fibres against the sides of the axe. From this fixity it must be released, and this is usually done by action on or near the head. For this purpose the workman slides his hand along the handle, and, availing himself (if need be) of the oval form of the handle after it has passed through the eye of the metal, he releases the head. The instrument has now to be raised to an elevation; for this purpose his hand remains near to the head, so causing the length of the path of his hand and that of the axe-head to be nearly the same. The effect of this is to require but a minimum of power to be exerted by the muscles in raising the axe; whereas, if the hand had remained near the end of the handle most distant from the head, then the raising of the axe-head would have been done at what is called a mechanical disadvantage. Indeed, if a workman will notice the position of the hand (which does not slide along the handle) before and after the blow has been given, he will find that its travel has been very small indeed. Remembering that

the power exerted to raise a body is in the inverse ratio of the spaces passed through by the body, and the point of application of the power, it may thus be obvious how great a strain will be on the muscles if the axe-head be raised by the hands at the opposite extremity of the handle. Reverse the problem. Take the axe-head as raised to such an elevation as to cause the handle to be vertical (we are dealing with ordinary axes, the handles being in the plane of the axe-blade). Now, the left hand is at the extremity of the handle, the right hand is very near to the axe-head—the blow is about to be given. The requirement in this case is that there should be concentrated at the axe-head all the force or power possible; hence to ease the descent would be as injudicious as to intensify the weight of the lift. Consequently, while with the hand nearest to the head (as it is when the axe reaches its highest elevation) the workman momentarily forces forward the axe, availing himself of the leverage now formed by regarding the left hand as the fulcrum of motion, he gives an impulse, and this impelling force is continued until an involuntarily consciousness assures him that the descending speed of the axe is in excess of any velocity that muscular efforts can maintain. To permit gravity to have free play, the workman withdraws the hand nearest to the head, and, sliding it along the handle, brings it close to the left hand, which is at the extremity of the handle; thus the head comes down upon the work with all the energy which a combination of muscular action and gravity can effect. The process is repeated by the right hand sliding along the handle, and releasing as well as raising the head.

FIG. 6.

The form of the axe-handle deserves notice, differing as it does from that of the sledge-hammer. In the latter it is round or nearly so, in the axe it is oval, the narrow end of the oval being on the side toward the edge of the axe, and, more than this, the longer axis of the oval increases as the handle approaches the head, till at its entrance into the head it may be double what it is at the other extremity. It often has also a projection at the extremity of the handle. The increasing thickness near the head not only gives strength where needed, as the axe is being driven in, but it also supplies that for which our ancestors employed the thongs as illustrated in Figs. 4 and 5. There is, too, this further difference—in a sledge-hammer more or less recoil has to be provided for, and the handle does this; in the axe no recoil ought to take place. The entrance of the axe-edge is,

or ought to be, sufficient to retain it, and the whole of the energy resulting from muscular action and gravity should be utilized. The curvature, too, of the handle is in marked contrast with the straight line of the sledge-hammer handle. The object of this curvature is worthy of note. In my hand is an American forester's axe. The handle is very long and curved. If, laying the axe-handle across my finger where the head and handle balance, I place the blade of the axe horizontally, you may notice that the edge does not turn downward; in fact, the centre of gravity of the axe-head is in the horizontal straight-line prolongation of the handle through the place where my finger is. Now, in sledge-hammer work the face is to be brought down flat, i. e., as a rule, in an horizontal plane. Not so with the forester's axe: it has to be brought down at varying obliquities. If, now, the hewer's hand had to be counteracting the influence of gravity, there would be added to him very needless labor; hence the care of a skilled forester in the balance of the axe-head and the curvature of the handle.

We must now consider the form of the cutting-edge as seen in the side of the axe. It is often convex. The line across the face in Fig. 7 indicates the extent of the steel, and the corresponding line in Fig. 8 the bevel of the cleaving edge. It will be noticed that the cutting-edge in each case is curved. The object of this is to prevent not only the jar and damage which might be done by the too sudden stoppage of the rapid motion of the heavy head in separating a group of fibres, but also to facilitate that separation by attacking these fibres in succession. For, assuming that the axe falls square on its work

FIG. 7.

FIG. 8.

in the direction of the fibres, a convex edge will first separate two fibres, and in so doing will have released a portion of the bond which held adjoining fibres. An edge thus convex, progressing at each side of the convexity which first strikes the wood, facilitates the entrance of successive portions from the middle outward. If the edge had been straight and fallen parallel to itself upon the end of the wood, none of this preliminary preparation would have taken place; on the contrary, in all probability there would have been in some parts a

progressive condensation of fibres, and to that extent an increase in the difficulty of the work.

The equally-inclined sides of the wedge-form of edge hitherto alone described as belonging to axes, and the equal pressure this form necessarily exerts upon each side if a blow is given in the plane of the axe, suggest what will be the action of an axe if the angle of the wedge is not bisected by the middle line of the metal. Assume that one face only is inclined, and that the plane of the other is continuous to the edge, then let the blow be struck as before. It will be obvious that the plane in the line of the fibres cannot cause any separation of these fibres, but the slope entering the wood will separate the fibres on its own side. Suppose a hatchet sharpened as previously described, and one as now described, are to be applied to the same work—viz., the cutting from a solid block the outside ir-

FIG. 9.

FIG. 10.

regularities—say to chop the projecting edges from a square log and to prepare it for the lathe. It may be briefly stated that the hatchet described in the second case would do the work with greater ease to the workman, and with a higher finish, than the ordinary equally-inclined sides of the edge of the common hatchet. Coach-makers have

FIG. 11.

much of this class of hatchet-paring work to do, and the tool they use is shaped as in Fig. 10. The edge is beveled on one side only, and, under where the handle enters the eye, may be noticed a piece rising toward the handle; on this the finger of the workman rests in order to steady the blade in its entrance into the timber in the plane

of the straight part of the blade, and to counteract the tendency of the wedge-side pressing the hatchet out of its true plane.

On Adzes.—Those whose business requires the forming of lengths of wood into curved shapes, and who rely upon the adze for the preliminary operation, use an Indian form of adze. In India it is held so near the metal that the workman's hand touches the metal. He accomplishes blows chiefly by acting from the elbow. This very general mode of holding gives a pretty uniform length to the radius of the swing, hence the form of the adze in the plane of the swing is nearly that of the circle described. The angle of the handle and the adze is very much the same as that of the handle of the file-maker's hammer and the head.

The Two-handed Adze.—When we look at the adze as used by English wheelwrights or shipwrights, we may well shudder to see how it is handled, especially when the cutting-edge is taken into account. The operation, briefly described, is the following: The workman stands with one foot upon the wood, this foot being in the line of the fibre. He thus assists in steadying (say) the felloe of a wheel. From this felloe much of the wood on which the sole of his shoe rests has to be removed. It will be noticed that the long handle of the adze is curved—the object of this is to permit an efficient blow to be given, and the instrument brought to a stop before the handle strikes any part of the workman's body; in fact, caused to stop by the exhaustion of its impact energy in and among the fibres of wood to be separated. The edge is often so keen as to cut through a horse-hair held at one end and pressed against it.

This instrument is raised by both hands until nearly in an horizontal position, and then not simply allowed to fall, but steadily driven downward until the curved metal, with its broad and sharp edge, enters near to, if not below, the sole of the workman's shoe, separating a large flake of wood from the mass; the handle is rapidly raised, and the blows repeated. This is done with frequency, the workman gradually receding his foot until the end-flakes of wood are separated. It is fearful to contemplate an error of judgment or an unsteady blow. William Tell and the apple on his son's head are, in another form, here repeated.

Fig. 12.

So skilled do men become in thus using the adze, that some will undertake, with any predetermined stroke in a series, to split their shoe-sole in two.

Curvature of Adze.—Clearly the adze must be sharpened from the inside, and, when the action of it is considered, it is also clear that the curvature of the adze-iron must be circular, or nearly so.

The true curvature of the metal may be approximately deduced from considering the radius of the circle described by the workman's arms, and the handle of the adze.

The edge of the adze is convex (Fig. 12), the projection in the middle being so formed for the same reasons as influenced the curvature of the edge of the axe already alluded to.

The curvature in the blade also serves (though partially) as a fulcrum, for, by slightly thrusting the handle from him, the workman may release such flakes of timber as are over the adze, and yet so slightly adherent as not to require another blow. Thus the adze when applied lever-fashion discharges its duty as the curvature in the claw

FIG. 13.

of a hammer does. Fig. 13 is a gouge-formed adze; a modification of this is used in making wooden spouts, and similar hollow work.

Many of the remarks applied to axes and adzes also apply to pick-axes. It may suffice to refer to two forms of this tool; they differ not so much in the operative points as in the size and distribution of the material.

The one used by paviors is long and light, and of large curvature; the other, used by stone-masons and quarrymen, is short-handled and heavy, much material being concentrated in the head. There is also another form of this instrument used on kegs, for the purpose of driving home the wooden wedges; in this form there is no point, the tool

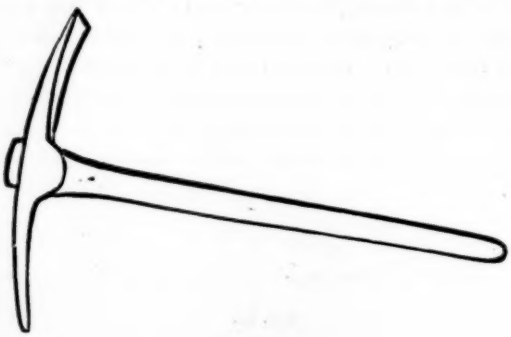


FIG. 14.

is rather that of an elongated hammer, the ends being provided with "panes" of different forms, set off at different angles. Such tools may properly be consigned to the class of hammers.

The pavior's, the mason's, and the quarryman's picks are the three to be very briefly considered. The first is properly a lever, and no

more; its pointed end is for entrance between stones, and then the wooden handle and the unemployed elevated arm of the pick are used as two lever-arms at right angles to each other; thus motion can be had in two planes for the varying character of the pavior's work.

Such an employment is never allotted to the stone-mason's pick. The object of this is to remove chippings from stone much as the single-angled edge of an axe or an adze would do with chips from timber. It is, however, pointed and not edged, because stones are not fibrous. The weight of the iron head corresponds exactly with that of a heavy hammer, and, so far as this particular feature is concerned, the considerations in relation to hammers apply.

There are peculiarities in reference to the points of these tools. The whole of the energy of the workmen is expended upon one point (in the carpenter's axe or the wheelwright's adze this energy is distributed over an edge from four to eight inches in length), hence the rapid wear of this point, and the necessity not of frequent grinding, but of frequent reforging and retempering. Any attempt at grinding up these points would be practically unsuccessful, made as these picks usually are, because of the mass of metal required to give that penetration resulting from the sudden stoppage of heavy weights. The ordinary picks are therefore sent to the smith's to be sharpened. For this purpose they must be removed from the handle; and this has suggested forms of eye and handle which might with advantage be used with some other tools.

The axes and adzes hitherto considered have been chiefly regarded as tools for the greatest amount of heavy work to be accomplished by a workman. They are at one extreme of the scale, the other extreme being the removal of such small flakes as to become shavings of varying thickness. In progressing from great to small, the order would be from the axe or adze with its weighted head to a separation of the cutting-edge and its necessary metal, and the weight which must give the blow. Hence, in this descending scale, we reach the chisel, struck by a mallet.—*Journal of the Society of Arts.*

SUBTERRANEAN STREAMS IN SOUTH CAROLINA.

By Rev. ROBERT WILSON.

NEITHER the formations nor the phenomena described in this paper are peculiar to South Carolina, and the general subject has been frequently investigated in other limestone regions. The present writer, therefore, desires merely to offer some results of his own observation and experience as a contribution to the scientific literature of the subject.

In that portion of the State which lies between the Santee and the head-waters of the Cooper commences a chain of so-called springs which present some exceedingly interesting features. Before describing them it may be well to note the surroundings. The face of the country is flat, without a single hill worthy the name. The soil is a sandy loam, and, being within the thermal influences exerted by the Gulf Stream along the entire lower coast-line for fifty miles or more inland, is well adapted to the culture of the "long-stapled," "black-seed," or "sea-island" cotton, but yields poor crops of corn, and no pasturage. The lower bank of the river is always covered by "the swamp," with its dense canebrakes and its heavy growth of cypress. The upland is a broad and rich belt, dotted with cotton-plantations, and well wooded with oak, hickory, gum, and similar trees. Winding about through this belt is a high ridge of sandy, barren soil, covered by the long-leaved or turpentine pine and a thick undergrowth of "scrub-oak." It is in the middle or plantation belt that the "springs" occur. In both swamp and pine-land the water is soft, while that of the springs is strongly charged with lime, and, unless boiled and iced, decidedly laxative. Good pure water can usually be obtained, however, within a few hundred yards from "pine-land wells," or "freestone" springs. The country abounds in game, especially the swamps—bear, deer, wild-cats, the gray fox, and other small quadrupeds, with turkeys, partridges, woodcock, snipe, and indeed all birds, common to the latitude. No rocks or bowlders are to be found. The springs occur at irregular intervals over a space of some thirty miles, at least; whether beyond that distance or not I do not know. They are not properly springs, there being no case which I can remember where any bubbling or oozing of the water occurs, nor is there any adequate outlet from any of the basins; a small and shallow stream, or "run," which is soon absorbed by the swampy soil, being the only way of escape for the water, while in some cases, as we shall see, there is absolutely no way for it to escape.

Let us now proceed to examine a few of these basins in detail. The most remarkable of them all is on the "Woodboo" plantation, about forty miles from Charleston. Walking toward a clump of tall cypresses, you suddenly find yourself on the brink of a miniature lake, the ground being firm up to the water's edge. An irregular basin, about fifty yards long by a dozen wide, is hollowed out in the blue limestone-rock which underlies the soil but a few inches from the surface, and this is filled to the brim with slightly opaline yet perfectly clear water. The bottom slopes abruptly from either side to the middle, where it is fully twelve feet deep, and where exists an irregular fissure extending the whole length of the basin, and varying from two to six inches (apparently) in width. The basin swarms with fish of every variety common to the waters of the region, and of every size. Schools of fry keep near the edges, hundreds in number, while

in the deeper water may be seen full-grown perch and bream, catfish, black bass, pike, and alewives. Watch the bottom for a while, and you will see these fish issuing from the fissure in the rock, the larger bass (four to eight pounders) never venturing far from it, and darting into it at the least alarm. I well remember a pike nearly three feet long which I have often struck with a fishing-cane, but which I never could capture. The largest fish will not take the hook, on account of the exposure to view; but the smaller bream, perch, and bass, bite with great eagerness, and I have often caught from twenty to sixty in an afternoon, selecting the best fish by sight, and placing the bait at their very mouths. Sometimes the basin is almost empty of fish; an hour afterward enough will be visible to overstock a dozen ponds of equal size. By day eels are rarely visible, and you may stir up all the patches of grass along the bed without discovering one; at night they are frequently caught, the negroes sometimes "gigging" them of the largest size. The temperature of the water is the same winter and summer, about 62°, and the fish bite best in the coldest weather. I have examined the sandy margins at all seasons, and have never seen a fish-bed in this or any other of the springs. They do not breed in them, and indeed could not possibly do so.

From the lower extremity of this large basin proceeds the "run," a shallow, winding stream down which the larger fish could not possibly make their way. Indeed, I once caught a two-pound bass stranded, having essayed the passage and failed. Following this run about five hundred yards, we come suddenly on another busin, circular in form and much smaller than the first. Its greatest diameter is probably not over fifteen feet, while its greatest depth, near the centre, is fully ten. The bottom descends like a huge funnel, but on one side there is a projecting ledge of rock, under which, sloping downward in a direction away from the upper basin, is a hole seemingly about a foot in diameter. Out of this hole bass and pike of the largest size are seen to emerge, while the upper basin is filled with small bream and sunfish, biting readily at angle-worms, and occasionally a large red-bellied perch, a species rarely seen in the basin, will dart from under the rock-ledge and seize the bait. The little stream is lost at this basin, which has no outlet, but is surrounded by a wet, swampy piece of ground. Not far from these basins marl has been extensively dug, and one or two beds of greensand have been found, but I never knew the hard limestone-rock which forms the bottom of the springs to be struck in any of the excavations.

Proceeding now in a northwesterly direction, we find another of these basins on a plantation about two miles off. The ground falls suddenly into a little valley about twelve feet deep and six or seven wide, at the head of which stands a very old oak-tree, growing on the upper level. On the southeast the roots have been exposed by the washing of the clay soil, and immediately under them lies the spring.

This is a basin inclosed by an octagonal brick wall, where, for a century or more, the washing of the plantation and other such matters have been performed. Directly under the oak-tree is a ledge of rock, over which the water is about two feet deep. It grows more shallow toward the "run," where its depth is but a few inches; the entire basin is about thirteen feet by ten. The above-mentioned ledge of rock forms the roof of a cave-like aperture some eighteen inches high by three or four feet wide, into whose dark recesses the eye cannot penetrate, the bottom sloping away in a northwesterly direction under the hill which sustains the old oak. Schools of minnows frequent the shallow part, and hide in the water-grass; stir this grass with a cane or stick, and occasionally you may frighten out a small bream or sunfish, but very few fish of any sort are seen in the shallow basin, and these few refuse the most tempting bait. Now, the proper rock-basin here lies just in front of the cavernous opening, and is some six feet deep, but scarcely four in diameter. Drop your line *there*, and, if all is quiet, in a moment your float will dart diagonally down under the rock, and you may draw out a yellow-bellied perch, a blue bream, or a sun-perch of half a pound weight. Look in, and you will see huge bass lying with their heads only visible at the opening, or flashing their silvery sides as they turn into its unknown recesses. I once detected a pair of white eyes peering from the grass at the mouth of this cavern, and, dropping my bait just in front of them, was astonished at hooking an enormous mud-fish; this fish must have weighed five pounds, and he carried several yards of tackle right into the bowels of the earth, whence it soon emerged *minus* hook and lead. The "run" to this basin is not more than three inches deep anywhere, and sinks entirely into a quaking bog some hundred yards from its source. No fish over an inch long could swim seventy yards from the basin, and there is no communication whatever with any other water.

Leaving the "Pooshee Spring," we now ride a little to the east of north, and, at the distance of about two miles, we reach "Moore's Fountains," the most remarkable of the group. Crossing a little "bay" in the pine-land, you notice under your feet a miniature Natural Bridge, a span of rock about six feet wide covered with earth, and a little hole full of clear water on either side. Walking among the pines about a hundred yards to the right, you reach the "Fountains," six or seven holes in the ground, the largest of which is about five feet by eight, and in general character like the larger basins before described, but much more shallow. All these holes contain large numbers of small perch and bream, which bite readily in the winter, but are hardly worth catching. A little to the right of them used to stand two large twin-pines, and directly between their roots was a hole not more than two feet in diameter, and which you could not detect until you stood on its very edge. (I use the past tense, as the

trees may have fallen in the ten years since I stood beside them.) This hole seems to go sheer down into the earth, and I have never been able to sound its depth with the longest fishing-line or rod which I had with me. Setting my float about ten feet deep, however, and "bobbing" into it by hand, I have caught, from between those trees, from thirty to sixty good-sized bream and perch of different species, in the course of two hours. The float would go straight down, as if the fish were descending into the bowels of the earth.

The next spring of which I know the existence is at "The Rocks" plantation, some twelve miles away, and the last of the chain is the famous "Eutaw Springs," where a battle was fought during the Revolution. At the latter place there are two openings, some distance apart, and tradition says that an Indian once dived into one and emerged from the other. I do not know whether fish are caught in these or not. No connection has ever been traced between these springs, or fountains, and the neighboring rivers, either of which—the Santee and the Cooper—is many miles away. Here, then, is the proof of a subterranean stream, or more probably lake, inhabited by fish in immense numbers, and of the same species found in the neighboring waters. These fish have perfect eyes, and differ in no respect from their fellows of the ponds and rivers, except that they invariably present that bright, clean appearance characteristic of fish taken from pure, clear water. They must pass freely through the whole course of the underground caverns, for, were all the open basins put together in one, it would not afford food or breeding-space for one hundredth part of the number found in any one of them, and they must live most of their time in utter darkness, for the little openings at which they appear are few in number and many miles apart. The indications seem to be that this enormous subterranean cave or water-course is hollowed out through a narrow stratum of limestone-rock which winds its way in a southeasterly direction; but it may be of far greater extent. Near Pineville, some ten miles from the nearest spring, and considerably off the course, there is a certain spot in the public road where the sound of the horse's feet is precisely like the noise made in crossing an earth-covered bridge, and tradition tells of treasure buried there in Revolutionary times. The water in this section shows no lime, nor indeed does it anywhere except in the springs themselves. The negroes of the region have invested these springs with a supernatural interest, peopling them with water-spirits known as "Cymbees," resembling in their imaginary characters the Undines and kelpies of the Old World.

MATHEMATICS IN EVOLUTION.

By GEORGE ILES.

WHILE we know that only Infinite Intelligence could reduce the entire phenomena of the universe to mathematical expression, it affords an observer constant surprise to find primitive laws of order and number recur again and again amid the infinite variety of Nature.

The spectroscope would seem to indicate that the elements of our present chemistry are really very complex structures, yet we find them, when grouped in all sorts of proportions as molecules, capable of crystallizing in forms of perfect geometrical symmetry, often of much simplicity. In botany, where the factors both chemically and mechanically are extremely various, we find simple laws obeyed in the disposition of leaves, flowers, and parts of flowers; a remarkable instance of which occurs in the growth of leaves on spirally-leaved plants. In the first order of them, a leaf is found in $\frac{1}{2}$ the circumference of the stem, and throughout the series the arcs occupied by a leaf are respectively $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, and $\frac{13}{34}$, of a circle, the numerator and denominator of each fraction being those of the two next preceding added together.

In the highest plane of Nature, that of animal forms, the conditions fulfilled are too complex to permit any formulation of lines and angles, but natural history in its first chapters gives us the habitations of the nautilus and other organisms low in the scale of life, which in their beautiful volutes and spirals embody simple geometry. So also does the architecture of our common insects, the bee, wasp, and spider, which, wonderful as it is, must remain less so than the work of the microscopic coral zoöphytes, which, while severally living and building where it is easiest, yet unconsciously coöperate through successive generations to complete a structure of comparatively vast proportions and much symmetrical unity.

These few examples, which might be multiplied indefinitely, may serve as bases for the opinion that complex wholes, acting in many cases like simple ones, may be more easily reducible to mathematical treatment than might at first view be supposed, from the number and variety of ultimate factors concerned in any given problem. Nature would seem to act by but few first principles, which she constantly repeats in her various fields, and which, combined in different ways, yield all her infinite manifestations. The scientific progress of our times is marked by the continual absorption of diverse laws into higher and more general ones; thus the forms of force that used to be thought distinct entities are now proved to be interchangeable, and therefore essentially the same. A minor instance of a like kind occurs

in the recent investigation of wave-motion. The old notion was that the particles in water-waves moved up and down in straight lines, but the fact has been demonstrated that they roll in circles having a diameter equal to the amplitude of the wave; this holds of all wave-motion, including light, so that the movements of the planets, as they turn on their axes and circle round the sun, are conveyed to our sight by an ethereal motion of precisely the same kind.

Although mathematical studies find ample illustration in Nature, an exaggerated love of symmetry may be induced by them, causing an enthusiast to pass legitimate bounds in an effort to over-simplify intricate problems; thus Kepler attempted to harmonize the orbits of the five planets with the boundaries of the five regular solids successively contained in each other. Such a vagary, however, could be pardoned in the author of the three immortal laws of astronomy.

In the present stage of knowledge so few of the sciences are exact, that any application of mathematics to the vast and complex processes of evolution is only allowable when the laws considered would be so powerful, did they work in an open field, that, though veiled by many weaker ones, they remain distinctly discernible in the salient features of Nature.

A valid application of this kind is made by Mr. Darwin in his theory of natural selection, where he states the tendency of organisms to multiply according to the law of geometrical progression—a tendency which he shows counts throughout the mazy conflict of forces affecting organic life. The purpose of this paper is to trace some effects of other such laws, in their theoretical simplicity so extremely potent, that their results persist through all practical qualifications, and so, when shown to account for observed facts, may serve as tenable ground for inference and deduction.

In evolution heterogeneity is a constant measure of progress, hence the laws stating the variety of effects producible from given elements have a direct interest and value. These are the laws of combination and permutation. Combinations, mathematically, are groups where the presence and not the position of an element counts for difference —thus B C A and B A C are the same combination but different permutations. As additions are made to the elements, combinations increase in geometrical progression with 2 as constant factor. Thus 2 elements yield 4; 3, 8; 4, 16; until, when we reach 63, the number of elements in chemistry, we find more than nine quintillions of combinations to be possible. This law tends to hold only in cases where the particular position of an element in a group is indifferent, as in the superimposition of colors in light; as in the simple molecules of chemistry, where, for instance, the result is the same, whether H^2 unites with O, or O with H^2; and as in all merely mechanical mixing of ingredients in manufacture, as pottery, gunpowder, and so on. Such cases are less common in Nature and art than those in which definite

positions are points of difference, as we find in the atomic grouping of compound molecules, where the phenomena of isomerism appear; in the order of successive sounds, whether in language or music; and as in the various series in which muscular and nervous forces coördinate in animal movements. In all such cases the multiplication of effects tends to follow a law of even greater increase than that of geometrical progression—namely, the law of permutations.

If A B C be elements given, their permutations in groups of 3 are 6 ($3 \times 2 \times 1$), in groups of 2, 6 more, and adding 3 for the elements taken singly, 15 is obtained as the number of permutations of all kinds. The addition of a new element increases them to 64 ($15 \times 4 + 4$), and so on in a ratio increasing with every additional element, until we find that 10 produce 9,856,900 permutations, and but 1,024 combinations.

These abstract laws are paralleled by the multiplied results which follow in the wake of any important invention or discovery. Forty years ago the main arts of representation were five in number—sculpture, painting, printing, engraving, and lithography. The art of photography, introduced by Daguerre in 1839, and since so beautifully developed, is continually increasing derivative arts. It is applicable to every other main art, and may become an element in new permutative groups of them. It has already given aid to the sculptor, the painter, and the engraver, and in the heliotype and woodburytype exhibits relations with lithography and printing; besides, it has added to human power in many other ways, has made the stereoscope available, bringing the natural beauties and artistic treasures of distant lands vividly near; it has aided astronomy in fixing views of transits and eclipses of brief duration, and in mapping the sun and moon; the physiologist has used it to preserve the evanescent exhibitions of dissection; and in observatories it accurately marks the minute movements of delicate apparatus. It limns the interiors of pyramids, catacombs, caves, and mines, giving incidental help to archæology and geology; and, in regions inaccessible to man, pictures the depths of the sea. It serves in war—and might in peace—to aid the topographer in mapping plans of city and country; in times of siege it has reduced correspondence to microscopic limits for carriage in the only possible way—by birds; and from year to year this wonderful art continues to be applied in new and valuable uses.

The illustration it affords of the manner in which human resources are multiplied by the accession of a new discovery might be repeated, were all the applications and results of the steam-engine, locomotive, or telegraph, traced in their numerous ramifications. So far from these mighty achievements exhausting the conquests possible to man, they are merely centres of new circles of power from which he may successively penetrate into the ever-boundless regions of the unknown.

The late Mr. Mill, at a period of great depression in his early life,

found relief in the charms of music, and strangely enough dreaded an exhaustion of it, just as many other people who have not the excuse of morbid ailment think that all the greatest possible discoveries have been made, and that all the finest things in prose and verse have been said. Such notions are denied by the laws which have been stated, as exemplified not only in the diversity and might of modern achievement, but also in the deep relations between the elements of natural action divulged by their very multiplication of effects; the generalizations of this age have never been equaled in scope and force—the persistence of force and the theory of evolution.

As sciences advance, their essential unity becomes more and more evident; methods that at first view would seem utterly unconnected are being constantly found to have a secret and helpful family tie. The comparative value of various types of bridges has been investigated by submitting glass models duly weighted to polarized light, which shows at once the distributions of strain and pressure. A common magnetic needle has been successfully employed in finding weak places in iron and steel axles by its unequal deflection at such points, due to internal heterogeneity in the mass examined. At Paris recently an underground pneumatic tube became obstructed at an unknown point; excavation was correctly guided by the adoption of an acoustic principle; a loud sound was made at the tube's entrance, and the time occupied before the reflected wave returned was carefully noted, from which was inferred the distance traversed by it to and from the obstacle. Many instruments at first made for purely philosophical study have been drafted into the world's practical uses. Applications of the rheostat and Wheatstone's bridge serve to locate the oft-recurring breaks in ocean-cables and telegraph-lines, and have very lately yielded the marvellous duplex and quadruplex telegraphs. The spectroscope, originally directed to the heavens, has now found uses on earth of great value; it detects adulteration, marks defectiveness in drainage, and points out impurities in water-supplies.[1]

[1] A proposition in pure mathematics may receive elucidation and extension by an illustration taken from optics. In Newton's "Principia," book i., section xii., prop. 70, he proves, in a manner very difficult to follow, that a corpuscle placed within a hollow sphere, if attracted as the square of the distance by all the points in the concave surface, will remain unmoved wherever placed, as the sums of attraction always balance.

This may be made clear not only of a spherical surface, but the closed interior of any surface whatever, provided it has no reëntrant angles, as a pyramid or an obliquely-truncated cone.

For, imagine the corpuscle to be luminous and to be bisected by any plane extended so as to cut the containing hollow surface into two parts, it is evident that equal amounts of light are radiated by each half of the corpuscle on each of the two parts of the surface containing it. Now, these rays diminish in intensity as the square of the distance, and so reciprocally correspond with a force emanating according to the same law from the surface and affecting the corpuscle. Hence, the area of the surface of any hollow body, having no reëntrant angles, varies as the square of its average distance from any point within it.

So that, in the tree of knowledge, as the branches grow in all directions, their offshoots come to touch at innumerable points.

The multiplication of effects may be traced not only in physics, chemistry, and cognate sciences, but also in the chapters of natural history and the facts of human life. The organized faculties of an animal which are distinctly different may be considered—of course, with proper qualification—as elements which may be grouped permutatively in the various actions directed to aid maintenance or promote safety; although, in the case of any particular variety of a species, a vast discrepancy must exist between the theoretical results of the mathematical law and the number of different groupings really made, yet, if the discrepancy is tolerably constant in degree in any two successive cases, the relations between two such cases may be stated by the law with an approximation to truth. Thus if a variety of quadrupeds with, say, four distinct and presumedly averaged powers be taken, at first sight it would seem but one-third better off in the struggle for existence than another variety with three several powers; yet the one may have an advantage over the other as great as four to one, for the variety of actions possible to the former may cover a field four times as great as the others. This aids us in understanding why variations in useful rather than those in useless directions tend strongly to persist. They do so because of the immense exaltation of power that comes with the development of any new faculty, any new means of securing a livelihood or escaping danger; and so great is this exaltation that even minor degrees of development have an appreciable value and tend to become permanent and to increase.

The effects of the laws under consideration also help to make clear why transition periods in organic Nature have been brief as revealed in their infrequent traces in such geological records as we possess.

When new circumstances have demanded the acquisition of new powers, or rather the development of dormant ones, the odds have been overwhelming against such individuals of a race as have been inelastic in the required direction, so that in a comparatively short period all that lived knew the new lesson.

A further corollary which harmonizes with observed facts is that, as species progress, an ever-increasing width of gap would separate kind from kind, and the highest individual of a kind from the next below it. The lowest organisms, monera, have no definite shape; polyps, some grades above them, conform very tolerably to a certain outline; and so on in the scale of life an increasing individuality keeps pace with an increasing divergency, until man and the tree mark the two great summits of Nature in her animal and vegetal forms.

Many able students of the theory of evolution stop short at the chasm which divides the human climax from the allied primates, and hesitate to believe that there can be a common origin for apes and the race which has produced a Beethoven and a Raphael; but a con-

sideration of the laws which have been stated, and which are closely borne out by observation, would lead us to expect just what we find, namely, in the processes of development intermediate links would drop out after comparatively brief existence between planes of life increasingly separated, so that the last difference of power and intelligence would be the greatest of all.

And, furthermore, the same laws make intelligible the vast gulfs we find fixed between our intellectual giants and the rest of mankind, so that they form a small solitary band above us all, leaving a mere understanding of their mighty works the test of our highest powers. A single English dramatist and a single English mathematician have probably equaled in scope and excellence of original work, in their several fields, all the like labors of their countrymen put together.

Two other mathematical laws, abstractedly of great power and generality, may be noticed in the many phases of evolution, namely, those treating of the relations between areas and solids of the same form, varying in size. In like plane figures, boundaries increase directly as like dimensions and areas, as the square; in similar solids, surfaces increase as the square and contents, as the cube of like dimensions. These laws state in an abstract way the economy of aggregation, whether domestic, industrial, social, or political. The farmer profits by them when he takes down costly fences in enlarging his domain; the ship-builder avails himself of them when he models his monster craft which shall carry the cargo of half a dozen small vessels at half the expense; the Broadway architect embodies them in his lofty designs, rivaling in a business structure the height of a common church-steeple, putting two ordinary buildings on one lot of ground.

From the time when animals first noticed that two together were stronger than two singly, the gregarious instinct has been assisted in taking a firm hold on many species from its usefulness in attack and defense; where it is not exhibited, exceptional circumstances prevent: for instance, a spider would have nothing to gain by going into partnership, for it preys on flies much weaker than itself, and no company of spiders, however large, could do battle with a swallow, or a housemaid armed with a broom.

Speaking in a general way, such savage tribes of men as have had the strongest social feeling, and the largest mutual confidence, have, other things equal, had an advantage over less coherent neighbors, and so on, until now modern history deals with national groups fewer than ever before, and becoming fewer still.

In commerce, also, the largest banks, mercantile firms, and factories, grow continually larger by virtue of the less expense attending the management of extensive groups. The costly competition of many small manufactories and merchants is passing away before the more economical methods of a few strong concerns. Coöperation in

labor, and in the supply of a community with goods, has succeeded to an encouraging extent in Europe, and in some degree on this continent.

In domestic life, also, the burden of sustaining the usual isolated homes is beginning to be thought grievous and unnecessary. The constant repetition of the same details on a small scale, in cooking, warming, and attendance, is evidently subject to a large discount in cost, and increase of comfort, when a number of families combine to have a single kitchen, heating-furnace, and corps of servants. Many solutions of this problem have been attempted with various success; large houses rented in flats, copied from European models, adorn some of the chief streets of New York and Boston, and hotels on all sorts of systems are to be found in our principal cities, numbering among their patrons thousands of families. It may be reasonably expected that in the near future some plan will be arrived at, and widely accepted, combining the benefits of individual homes with the advantages of association; but, for this result, an improvement in our present crudeness of social feelings must take place. Great is the premium placed on the growth of mutual harmony and confidence, yet how slow that growth is!

A process analogous to aggregation is that of concentration, which marks many of the forms of progress. When a force operates against a lesser one of constant amount, concentration multiplies its efficiency.

If a common furnace's heat is 3,500°, and a temperature of say 3,000° is required to melt iron, then but 500° of 3,500° are available for that purpose; but, when the same quantity of heat is presented at 4,200°, 1,200° of 4,200° may be utilized, an efficiency twice as great as the former. Hence the value of such an invention as the hot-blast, increasing the intensity of flame: the inert and diluting nitrogen is mingled with the oxygen of common air by the feeble force of diffusion; if they could be cheaply separated, it would mightily enhance the value of coal. Steam-engines, as now constructed, rarely yield in work more than a tenth the equivalent of heat applied; the chief waste is in the exhaust-steam, which, although in immense quantity, is of too low a temperature to raise more steam. Any feasible plan of concentration is all that is wanted to make the steam-engine more powerful; its duty has already been nearly doubled by the use of much higher pressures than Watt employed or sanctioned. A pebble on a sea-beach may have been exposed to the sun for ages without perceptible effect, but the focusing of a lens may reduce it to the liquid state in a few moments with no more solar beams than might have otherwise idly fallen upon it in an hour. This same principle also obtains in the operations of trade and business: the expenses of a railroad, steamship, or hotel, are pretty constant, and a certain amount of patronage pays them; beyond this point profits rapidly accumulate, and below it so do losses; small fluctuations produce large results in the balance-sheet.

Successive increments of difference in degree may gradually merge and become exalted into a difference in kind. A number of pendulums might, if unresisted, vibrate in an arc forever, but, if on one of them the movements of the others are suitably concentrated, its arc will gradually increase in amplitude until it becomes a circle.

This principle of concentration appears in organic Nature in the physiological division of labor, and in the adaptation of every organism to some particular environment which may be to it its field and kingdom. Analogy would lead us to suppose that the different duties of the brain are performed by special parts. So directly profitable has the division of labor been found in manufacturing industry, that in many cases it has been pushed to an injurious extreme, for a man is stunted in development when all his powers of mind and body but one remain unexercised. Specialists in art and science discover that their highest excellence can only come with a comprehension of wide principles and study in many various fields.

So far from concentration being invariably useful, diffusion may be a process incident to progress. A lump is soonest leavened by leaven distributed throughout it, crystallization proceeds more swiftly from separate nuclei than from a concrete mass. Analogously, the best, wisest, and most talented men of a people exert a larger influence when scattered through it than if gathered into an over-centralized capital, where they radiate chiefly on each other.

In the laws which have been considered thus briefly, it has appeared that their tendencies are continually progressive; that, while the capital of evolution is being increased, so also is the rate of compound interest by which it accumulates. It is now fitting that some of the causes should be noticed which reduce these tendencies from their theoretical power to the moderate activity we find them really presenting.

A minor and unfavorable sort of natural selection is that made by animals not carnivorous when they have a choice of food; they take the best to be had, and leave the rest to propagate its kind. This residue may be very bad indeed, when the total supply is scanty; in crowded pastures the grazing herds only permit the worst parts of the clover to come to seed, and squirrels always first eat the best nuts stored in their hiding-places, and any surplus that might germinate and grow is commonly of a very poor kind. The acquisition of new powers by an animal is usually accompanied by a gradual and injurious loss of its original ones; neither the omnivorous hog nor the higher primates can number readiness in swimming among their resources, although their inferior ancestry doubtless could. The introduction of machinery is steadily causing us to lose the deftness and dexterity of the old, unaided handicrafts, yet never so much as now were knack and skill of value, for they are indispensable to the designer and inventor in their work. A highly-cultivated citizen of New York, when he pene-

trates the wilds of the far West, must have an Indian to guide him through prairie and forest, for the red-man's perceptions of the phenomena around him remain keen and almost intuitive.

Modern arts vastly outnumber ancient ones, yet do not include them all; antiquity possessed many, either lost by neglect or by being secret with individuals and perishing with them, or perhaps in the extirpation of small, highly-gifted communities by overwhelming barbarous hordes.

The vast preponderance of mediocrity over exalted talent has always limited the influence of intellectual greatness, and at times even perverted it to confirm the low standard of a community's intelligence instead of raising it. A key in metaphor is always something unlocking or unfolding the hidden—this refers to but half the business of a key—it is also used to bind, lock up, and secrete. History furnishes many examples of an unusual might of mind permitted, by the lack of appreciation for its best work, not only to leave it undone, but induced to acquire power by mystifying difficulties instead of resolving them, and so to retard progress by an exertion of the very capacity that might assist it.

The individuals of a community rise pretty much together, and the voice of circumstances is not so loudly "Be your best," as "Be fit." The limit to the practical value of greatness becomes plain if we imagine Kepler, while making a scientific journey, to be suddenly surrounded by hostile Sioux. We can believe that the world may not know some of its greatest sons, for greatness is known only when allied with the talents of publicity and the circumstances of appreciation.

Truths and suggestions beyond the comprehension of hearers have doubtless often been uttered in vain. Our guides in the path of knowledge must keep within easy distance if they are to be useful. Huyghens, the great Dutch philosopher, clearly propounded the wave-theory of light, but it remained unnoticed in his times, to be rediscovered a century afterward, when the minds of scientific men had been prepared to receive it.

Then, again, the very intensity of appreciation bestowed upon genius may be hurtful, in the diversion of men of some original power from the development of themselves into the army of mere repeaters, imitators, and quoters. Besides, when the leaders of thought and investigation have erred, as at times they inevitably must, the mistaken opinion from the weight of a great name becomes a clog and a barrier. Newton's emission-theory of light delayed the true explanation through many weary years; and zoölogy is still suffering from the belief in catastrophes entertained in the mighty brain of Cuvier. And, further, physiologically, the antagonism of growth and reproduction has left the chiefs of men either childless, as Kant, or continued in a puny race, as Cromwell. Talent is hereditary, but genius scarcely.

Progress is also thwarted by the sub-evolution of evil. In human

societies, as mutual trust and confidence advance, they are liable to be rudely checked from time to time as the rewards of the liar and thief temptingly increase. The very perfection of mechanical appliances is used by the burglar and counterfeiter, and only a high degree of educated ingenuity and a world-wide mercantile good faith could have made such a fiend as Thomassen possible. The invention of new machinery, the manufacture of new chemicals, the extensions of mining, and the commingling of increased travel, in their accidents and sometimes in their baneful results in common pursuit, render the tasks of physician and surgeon more difficult than ever before. The complications of modern life are so great and varied, that the moral laws do not possess the direct and simple force they had of old; in the surge and vortex of to-day it takes a keen intellect to separate right from wrong, and many err because their consciences are not reënforced by education for the new exigencies.

Evolution is underlaid, as is all change, by the greater law of the persistence of force, ever holding the even balance through all complexity, maintaining throughout all a just compensation. Every new faculty and enjoyment is earned by its equivalent of work, trouble, or ill; with every addition to power comes an addition to wants, to labor, and the possibilities of pain. As the stores of the mind increase so also do ideals craving satisfaction become higher and wider: ever "on the isthmus of a middle state," man is at once a record of the past and a prophecy of the future; limited by his inheritance to definite acquirement, he yet aspires, by nascent impulses, for such better things as only his posterity can ever possess.

EXPERIMENTS ON HYPNOTISM.

By FRANKLIN CHASE CLARKE, M. D.

SOME time ago my attention was called to two articles on "Hypnotism in Animals," in the columns of The Popular Science Monthly,[1] in which I became very deeply interested.

For the sake of those who may have forgotten what the author, Prof. Czermak, said in regard to these very curious phenomena as observed in fowls, I will briefly describe his mode of proceeding, and afterward give the results of my own experiments.

And, first, of the crawfish experiment. If a crawfish is held firmly in one hand, while with the other "passes" are made along the back of the animal from head to lower extremity, the animal will become so quieted as to allow itself to be placed in any position whatever, even the most unnatural, without once stirring. Among people generally

[1] September and November, 1873.

this has been called "mesmerism" or "magnetism." Prof. Czermak proved that neither magnetism nor mesmerism is active in the production of this phenomenon.

This case is simple enough, that of the fowls is more complex. It has been thought that if "a chalk-line" were drawn the length of a hen's beak, or from eye to eye across the beak, while held upon a flat surface, she would remain perfectly quiet for more or less time when the hands were removed. I think this is commonly believed in our own country. Here, the chalk-line seemed intimately connected with the phenomenon.

Kircher varied the experiment by erasing the chalk-line. He also tied a ribbon around the legs of the fowl, and then removed it; and the hen still remained quiet. According to him the imagination of the fowl plays an important part; and he laid great stress on the acts of "tying" and "chalking."

Prof. Czermak does not attach much importance to Kircher's conclusions, in his first lecture. But, in his second, he seems to believe that the "tying and chalking" exert some slight influence through the imagination. He relies mainly, however, on the "stretching out" of the fowl's neck. Pigeons gave him more trouble in this respect; and this caused him to modify his theory to some extent. He agreed, however, that after a hen had once been subjected to this *neck-stretching* process, she could be caught and placed upon the floor or any other surface, *without* being again subjected to it; that is, hold her firmly until all struggling has ceased, and she can be placed in almost any position without once touching the neck. Here Prof. Czermak stops, and from this point my own experiments begin.

I first repeated many of his experiments on fowls, without using chalk and string, and with as successful results. Afterward I varied the mode of experimenting. Hens, ducks, cats, and canary-birds, have thus all succumbed to this peculiar procedure at my hands, and in every instance *without* my subjecting them once to "neck-stretching," except, of course, when I was repeating his experiments.

My first experiments, since repeated, were made upon some pet canary-birds when I was quite a child, and knew nothing of this phenomenon. I had three of these little birds, one male and two females. These I would often remove from their cage, hold them in my hand until they became quiet, and then place them upon the floor. In this way I would often have all three lying out upon the floor perfectly motionless. As to whether their eyes remained closed or not I have no recollection. The male was very wild, and, if not watched carefully, would fly from the floor.

This experiment I have since practised on a canary, and obtained the same results as I did when I first noticed the peculiarity. Here let me say again that I never touched the head or the neck of the bird.

When quite a lad, and residing in a Western State, I often observed the farmers brought their poultry alive to market, preventing the escape of the fowls by tying their legs together. The fowls, whenever I saw them, were always quiet.

Prof. Czermak thought that the stretching out of the neck of the fowl caused, in some manner, a "slight mechanical extension of certain parts of the brain, ... apart from the fear which the animal experiences," etc.[1]

Now, since my last experiments I dispensed entirely with all "neck-stretching." Prof. Czermak's explanations do not tend to throw that light upon the subject which he believed they would; and we must look to Kircher for a fuller explanation of this phenomenon—that of the power of the imagination.

Those parts, then, which it has been said were necessary to touch for the success of the experiment, I have latterly entirely let *alone.*

I usually, after catching my fowl, hold it firmly upon the ground, floor, etc., as the case may be, until all struggling has ceased. Then I remove my hands, making no "passes," nor any more movements than are necessary to take them away from the animal. Now I have the fowl stretched out before me motionless, and breathing deeply; the eyes are generally open. Some hens are more easily subjected to this experiment than others. Tame hens will allow much handling, and are hence never good subjects. A very wild fowl is an excellent animal upon which to make these experiments.

As in the cases instanced by Prof. Czermak, so I find different fowls must be differently treated. Some require to be held a shorter, some a longer time, than others. But this fact is evident, that the animal must be held firmly until perfectly quiet.

It was only the other day, while writing the above, I visited a neighbor's poultry-yard to verify still further my views upon this subject. After catching a huge Brahma cock, which I had great difficulty in holding, as he was very violent, I held him fast until *he* as well as I knew he could not escape, and then took away my hands. He lay just as quiet as though my hands were holding him. But his eyes were *open* and his head was somewhat raised from the ground. In this condition I placed him in his coop, where he remained in a most awkward position upon his side until a hen came along, and seemed to assure him of his liberty.

Thinking that the "stretching out of the neck and bill" had simply the effect of closing the animal's eyes, I held a duck firmly in one hand, and with the other threw my handkerchief over its head. The same phenomena resulted, but they were of shorter duration. I next treated a little bantam pullet in the same way; but, being a tame and gentle little creature, I could do almost anything with her. One singular feature was that, while upon her back, and the handkerchief over her

[1] *Vide* POPULAR SCIENCE MONTHLY, *loc. cit.*

head, she began to sing. She remained very quiet, but only for a short time.

A gentleman told me of a somewhat similar process he employed in the West, when he had entrapped in the same box several prairie chickens. It being difficult for him to hold more than one chicken at a time, he would take one from the trap, hold it until quiet, shake it a little, and then lay it upon the snow. Sometimes he would have two or three thus lying there with their eyes closed. They would remain in this condition long enough for him to secure the whole catch. But, if one chanced to open its eyes when he was not looking, it would most certainly escape.

The explanation of all this does not seem difficult. In fact, we do not feel obliged to bring forward *mesmerism*, *magnetism*, nor even *hypnotism*, as having anything to do with the phenomena. They result simply from fear, as any one may easily prove for himself: the animal appreciates the power acting on it, and the uselessness of resisting the injury or the supposed injury inflicted. Here, of course, we must allow animals a certain amount of intelligence for such perceptions. After the animal has made resistance, and finds itself incapable of removing the obstacle, it lapses into quietude, to act again only when it supposes the restraint has been removed.

Hence, Kircher, apart from his "ribbons" and "chalk-lines," or "remembrance of chalk-lines and ribbons," is not so far out of the way in believing these phenomena to be due to the power of the animal's imagination. The same thing, under certain circumstances, is observed in man, and every one must be aware of the power the imagination often possesses over him.

In the "charming" of the lower animals by serpents we notice similar phenomena. The *so-called* "charmed animal" cannot move, from the fact that it does not believe it can. It has no power of will to put into operation those muscles necessary to carry it from danger. In other words, it is paralyzed with fear.

The cat playing with the mouse still further illustrates the same principle. The mouse knows he cannot escape, for, at every attempt to move, pussy's paw is put gently upon him, and he is pulled back within her reach. Hence, after a while the mouse does not move at all unless pussy "stirs him up," so to speak, with her paw.

Hence we cannot see anything very wonderful, after all, in these phenomena: they depend wholly and only upon fear, and are but an illustration of the power of the imagination among animals, and add to the evidence daily accumulating of the possession by the lower animals of a certain amount of intelligence.

ORGANISMS AND THEIR MEDIA.

By H. CHARLTON BASTIAN, M.D., F.R.S.

HEAT and light are physical influences to which even the lowest units of living matter respond, whether their mode of life and nutrition is most akin to that of plants or to that of animals. These influences act on such organisms, either by stimulating, retarding, or otherwise modifying the chemical changes naturally occurring in their interior, and upon the existence of which their life depends. Where the vital processes of the organism are stimulated by these physical agencies, their incidence may, in many instances, become the cause of so-called "spontaneous movements." The term, however, as applied to movements, is a bad one—since all the movements of an organism are alike dependent upon a series of antecedent states of contractile and other tissues. There is some sort of foundation, it is true, for the popular mode of expression. A movement is not said to be "spontaneous" if it follows immediately upon some external impression as a cause; the term is generally applied where the cause of the movement is not distinctly recognizable. In some instances the undetected or unconsidered external cause may be the incidence of a diffused physical agent such as heat, which, by stimulating the vital processes, seems to give rise to spontaneous movements. In other cases so-called "spontaneous" movements are to be referred to internal states or changes, whose origin is even less distinctly traceable, to impressions, it may be, which emanate from some of the internal organs, and thence are transmitted to ganglia in direct relation with some of the organs of locomotion.

Heat mostly acts on organisms upon all sides alike, so that, though it may stimulate their life-processes generally, and, in some instances, give rise to movements, these movements are not determined in one, more than in another, direction. Thus, while heat stimulates the "to-and-fro" or the gyratory movements of bacteria, and also renders more striking and rapid those changes of form which all amœboid organisms are apt to display, the movements evoked are random, and apparently devoid of all purpose.

It is not altogether similar, however, with the influence of light. This agent almost always, and necessarily, falls more on one side than on another; and consequently it often suffices to induce movements to be made in definite directions, by the lower forms of life, just as it causes definite and responsive movements to be executed by certain parts of higher plants, which come fully under its influence. In each case the movement, or altered position, is due to some nutritive change; that is, to some alteration, whatever its nature, in the activity of the life-processes taking place in the part impressed by the

light. So that, whether we have to do with the movement of a sunflower, or with the locomotions of minute living units, the essential mode of production of the movement is probably similar. Of the actual locomotions of minute living units under the influence of light many instances might be cited; it will suffice, however, to mention the fact that any green zoöspores which may have been uniformly diffused through the water are very apt, when the vessel containing them is placed near a window, to collect on the surface of the water at the part where most light falls upon them. Minute animal organisms are, however, often affected quite differently by this agent. They are frequently caused to move away from, rather than toward, its source; so that the creatures thus impressed "seek" the shade rather than the glare of sunlight.

The action of such influences and the production of such movements form the beginnings or substrata, as it were, of other phenomena with which we are now more particularly concerned. The unilateral influence of light and the movements to or from its source to which it may give rise afford a connecting link between diffused causes like heat, which, by affecting the general activity of the vital processes in the organisms, may lead to purely random movements, and those more localized influences now to be considered, to which the various definite or responsive movements of organisms are attributable.

The first, because it is the simplest, of these localized influences to be considered is a shock or mechanical impact of some kind, falling upon the external surface of the organism. This is the primordial or most general of all the modes by which the surface of an organism is impressible, and its sensitivity to such stimuli is both in the stage of impression and the stage of reaction closely akin to the general organic irritability of protoplasm — which, indeed, unquestionably constitutes its starting-point. This mode of impression, moreover, is one which tends to establish a correspondence between the organism and the most common events or properties of the medium in which it lives and moves. It is consequently the mode of impressibility most extensively called into play among all the lower forms of animal life. And although the whole surface of an organism, or the greater part of it, in one of the simple animals to which we are referring, may be more or less impressible to shocks or impacts from contact with surrounding bodies, it often happens that such impressions more frequently fall upon, and are more readily received by, certain appendages situated at the anterior extremity of the animal, in close proximity to the mouth. Such specialized parts or tactile appendages are known as papillæ, setæ, tentacles, antennæ, or palpi, according to the forms which they assume in different animals.

Why such organs are developed so frequently at the anterior extremity of the animal, and in the neighborhood of the mouth rather

than on other parts of the body, is not difficult to explain. Whatever the mode by which they are evoked or called into being (and the most opposite views may be entertained upon this subject), it seems obvious that, if organs of this kind are to be present at all, they should occur in situations where they might be put to most use. In an animal accustomed to active locomotions, the mouth is, with only a very few exceptions, situated on that part of the body which is habitually directed forward. The anterior extremity thus comes to be the part of the body which is brought most into converse with its environment; and, of the diverse objects impinging against it, or against which it impinges, some are of a nature to serve the organism as food, and some are not. A higher degree of impressibility springs up, therefore, in this situation, where the parts are necessarily exercised so largely with impressions corresponding with food and with others having an opposite relation. It should not surprise us, therefore, to find among the lower animals that the most specialized tactile organs are found in the immediate neighborhood of the mouth. Such organs may be, and are in fact, not unfrequently both tactile and prehensile; though this is more especially the case in sedentary forms of life, like the hydra, the sea-anemone, or some of the tentaculated worms. The tentaculæ of the latter animals would seem to be possessed of an extremely high degree of impressibility, if we are to judge by the report of one who devoted much attention to the study of this class of organisms—the late Dr. Williams, of Swansea. He says: "It is not easy, for those who have never enjoyed the spectacle of the 'feat of touch' performed by the tentaculated worms, to estimate adequately the extreme acuteness of the sensibility which resides at the extremities of the living threads with which the head and sides of the body are garnished. They select, reject, move toward, and recede from, minute external objects with all the precision of microscopic animals gifted with the surest eagle-sight."

But it often happens that the solid bodies serving as food are in a measure soluble, so that, in animal organisms comparatively low in the scale of complexity, some of the tactile structures within or around the mouth may undergo a further specialization by which they become able to discriminate and respond to impressions of a slightly different nature. These parts become sensitive to a more refined kind of contact, such as may be yielded by certain dissolved elements of the food substance, whose local action may be attended by some slight chemical change in the tissue of the organ. Impressions are thus produced whereby the "sapidity" or flavor of bodies is appreciated, and such impressions gradually become associated with definite related movements.

No distinct organ of "taste" or specialized gustatory surface is known to occur among invertebrate animals, except in insects and in such higher mollusca as gasteropods and cephalopods; although such

a mode of impressibility does, doubtless, exist in many other of the lower forms of life. Impressions of the two orders already referred to —more or less distinct from one another—are those by which alone multitudes of the lowest forms of animal life, such as polyps, medusæ and various kinds of worms, appear to hold converse with the outside world. Touches and tastes are the names which *we* apply to the subjective effects of such impressions; and, though it is impossible at present wholly to ignore this point of view, or to use language which is not colored by it, I do not now wish to say anything with regard to the nature or intensity of the feelings that may be associated with corresponding impressions in the lower animals. The reader must for the present look rather to the objective effects of these impressions, and in so doing he will learn that these become organically associated with a nervous mechanism by whose intermediation they are able to evoke distinctive movements of a responsive nature.

Seeing, however, that tactile and gustatory impressions can only be made by actual contact of external bodies with the specialized parts of an organism, such impressions are not of a kind to excite movements in quest of food; although they may lead to correlated movements of parts adjacent to those which are touched, as when all the tentacles of a sea-anemone close round a body that has come into contact with some one of them. This effect is due to a radiation of the primitive stimulus, and we may see in such a set of actions only a more rapid and slightly more complex result than is known to follow the irritation of one of the peripheral tentacles on the leaf of a sun-dew. In the latter case the bending of the tentacle actually irritated is slowly followed by the bending of others under the influence of an internally diffused stimulus.

Movements in actual quest of food may, however, be excited in other animal organisms by impressions which suffice to bring them into relation with more or less distant bodies. The way is paved for this result when some portion of the anterior and upper surface of the animal, in which aggregations of pigment occur, becomes more than usually sensitive to light. A dark body passing in front of such a region gives rise to certain molecular changes therein, and these molecular changes differing among themselves become capable of exciting distinctive impressions in the organism which it gradually becomes attuned to discriminate. The power of discrimination in this, as in all other cases, is indicated by the organism's capability of responding to impressions by definite muscular movements—as when the oyster, with the valves of its shell apart, instantly closes them if a shadow is projected over certain sensitive pigment-specks or so-called "eyes" at the edge of its mantle.

This beginning of visual impressions truly enough shows itself as a merely exalted appreciation of tactile impressions; and, inasmuch as such an appreciation of the presence of near bodies would in so many

instances be quickly followed by a more gross mechanical contact, the rudimentary visual impression is, as Spencer says, a kind of "anticipatory touch." From this simple beginning, in which bodies only slightly separated from the impressible foci excite certain general or only vaguely specialized impressions corresponding to light and shade therein, the organs of sight and their impressibility gradually become more and more elaborate. To rudimentary aggregations of pigment transparent media are added, which condense the light on these impressible patches, and these media in other organisms are sufficiently like a lens to be adequate to form a definite image of an external body on the layer of pigment, which, on its other side, is in contact with a nerve-expansion communicating with a contiguous ganglion. Numerous simple structures of this kind may exist apart from one another, as in many bivalve mollusks, or they may be far more numerous and closely aggregated so as to form such compound eyes as are met with in crustaceans and in insects. Or individual ocelli may be perfected, as in spiders, or lower crustacea, though most notably of all among the cuttle-fish tribe in which two movable eyes are met with, whose organization is just as perfect as that of the eyes of fishes.

The difference in degree and range of sensitiveness existing between the simple "eye-specks" of some of the lower worms and the elaborate organs existing in the highest insects and mollusks is enormous. The range and keenness of vision become progressively extended, so that creatures with more perfect eyes are capable of receiving and appreciating impressions from objects more and more distant, and the various actions which become established in response to impressions habitually made upon such sensitive surfaces increase enormously in number, variety, and complexity. The relation existing between the keenness of the sense of sight and the powers of locomotion of insects has long been recognized by naturalists. Prof. Owen, for instance, thus alludes to it: "The high degree in which the power of discerning distant objects is enjoyed by the flying insects corresponds with their great power of traversing space. The few exceptional cases of blind insects are all apterous, and often peculiar to the female sex, as in the glow-worm, cochineal-insect, and parasitic stylops."

The various actions of insects and of invertebrate animals generally are, however, found to be easily capable of classification. They are, in the main, subservient to the pursuit and capture of prey, to the avoidance of enemies, to the union of the sexes, or to the care of their young. To such ends are their various motions, whether occasional or habitual, more or less directly related. Nothing is here said, however, as to the extent to which such ends are realized by the animals themselves.

In vision, as I have said, we have to do with a refinement of the sense of touch, whereby the animal becomes sensible of impressions

produced by "waves" of light emanating from a distance, and is thus brought into mediate contact with certain distant objects. A refinement of the organs of taste may also occur whereby bodies possessing sapid qualities are capable of impressing organisms still at a distance. Just as vision, in fact, is, in its most elementary phases, a sort of "anticipatory touch," so is smell a kind of anticipatory taste. Yet the two cases are not altogether similar. In vision, the contact—if it may be so termed—with the distant body is mediate, through the intervention of ethereal undulations; while in smell we have to do with a case of immediate contact, not with the distant body itself of course, but with extremely minute particles which it gives off on all sides. An "emission" theory serves to explain the diffusion of odors, though it will not hold for the diffusion of light. From what I have said it may be inferred that, as regards the delicacy of their respective physical causes, the sense of smell occupies an intermediate position between taste and sight.

It is regarded as a matter of certainty by naturalists that such creatures as spiders, crustacea, insects, and the higher mollusks, are capable of being impressed in some way by odors, and that their actions are to a certain extent regulated by such impressions. We have, however, no definite knowledge concerning the parts of the surface which in these, and perhaps in still lower organisms, are attuned to receive such influences. Although a rudimentary sense of smell seems unquestionably to be possessed by such aquatic forms of the invertebrata as crustacea and the higher mollusks, it is, perhaps, a sense-endowment which generally exists in a more developed and more varied form among air-breathing animals. In whatever forms of life it may be met with, however, the sense of smell seems to be very largely indeed related to the detection and capture of food; so, that, in these relations, it comes to the aid of the already-existing senses of sight, touch, and taste, though it has the peculiarity of being scarcely otherwise called into activity among the invertebrata.

Although we have no positive knowledge concerning the situation of the organs of smell among invertebrate animals, there is good reason for believing that in crustacea they are to be found at the base of the antennules; that in cephalopods they are represented by two little fossæ in the neighborhood of the eyes; and that in insects a power of appreciating odors is possibly possessed either by the antennæ themselves, or by a pair of fossæ near their bases. Another cephalic organ has also been referred to as possibly endowed with a power of being impressed by odors. Thus Owen says: "The application, by the common house-fly, of the sheath of its proboscis to particles of solid or liquid food, before it imbibes them, is an action closely analogous to the scenting of food by the nose in higher animals; and, as it is by the odorous qualities, much more than by the form of the surface, that we judge of the fitness of substances for food, it is more reasonable to

conclude that, in this well-known action of our commonest insect, it is scenting, not feeling, the drop of milk or grain of sugar."

Looking to the importance of this endowment in reference to the perception of food, and also looking to the situation of the organs of smell in all the vertebrate animals, there is good reason for believing that any similar organs of sense which may exist among invertebrate organisms would be found in close proximity to the mouth, so as to permit of that joint or associated activity between the sense of taste and the sense of smell which is met with in all higher forms of life.

As already pointed out, there are also obvious reasons why the principal specialized tactile organs that may present themselves in lower animals should be found in the neighborhood of the mouth; and for similar reasons, if for no other, the anterior extremity of the body, or the upper surface near this anterior extremity, is the site in which visual organs might be used with most advantage by their possessor. To an active animal, visual organs would not only be more useful at the anterior extremity of the body than elsewhere in relation to its food-taking movements, but also in reference to all other uses to which such appendages may be applied during active locomotions from place to place. To this situation of the eyes only two or three exceptions are met with among animals endowed with powers of locomotion, and these deviations are explicable by reference to the habits and modes of life of the organisms in question.[1]

The part of the body bearing the mouth, and the various sensory organs already named, is familiar to all as the "head" of the animal; and it is owing to the fact of the clustering of sense-organs on this part of the body that the head contains internally a number of nerve-ganglia in connection therewith. This aggregate mass of ganglia constitutes the brain of the invertebrate animals, which, as we shall find, differs much in different classes of animals, not only in disposition and in size, but also in respect to the relative proportion of its component parts. The size of the respective ganglia, indeed, necessarily varies in accordance with the relative importance and complexity of the several sense-endowments already mentioned—those of touch, taste, smell, and vision. The ganglia thus constituting the brain of invertebrate animals are not only connected with their own particular external organs, but, in addition, we find the several ganglia of the two sides brought into relation among themselves and with their fel-

[1] In some spiders the ocelli are situated rather far back on each side of the cephalothorax, but, as Siebold says: "The disposition and the direction of the organs are in relation with the mode of life of these animals, some of which wait for their prey hidden in chinks of a wall within silken tubes which they have constructed, while others hold themselves motionless in the centre of their webs, or wander from side to side, a mode of life which obliges them to look in all directions" ("Manuel d'Anatomie comparative," tome i., p. 308). According to Prof. Rolleston also in the crustacean genera *Euphausia* and *Thysanopoda*: "Eyes may be, contrary to the otherwise invariable rule in *Arthropoda*, found elsewhere than upon the head" ("Forms of Animal Life," p. cxxi.).

lows by means of connecting fibres, while they are also more distantly united with other nerve-ganglia in different parts of the body by means of commissural fibres.

But another special sense-endowment remains to be referred to. This has to do with the organism's power of appreciating sounds or "auditory" expressions—a power which is, however, probably possessed in only a low degree by most invertebrate animals; since, even in the most perfect form of the organ of hearing among them we have to do with a very rudimentary structure. In this respect there is a great difference between the sense of sight and the sense of hearing. While the eye of the cuttle-fish attains a degree of elaboration that does not fall so very far short of the most perfect form which it displays among vertebrate animals, the organ of hearing, as a mere organ, in all forms of the invertebrata is remarkable for its simplicity, and remains notably inferior to the highest type attained by this sensorial apparatus—which, with its nerve-connections, becomes so enormously developed in many mammals and in man.

Like the sense of sight and the sense of smell, that of hearing, even in its simplest grades, serves to bring the organism into relation with more or less distant bodies, so long as they are sufficiently sonorous to transmit the so-called "sound" vibrations through water or air to the sensitive organs which become attuned to receive such impressions.

An auditory organ does not seem to be present at all—certainly none has as yet been detected or inferred to exist—in many of the lower forms of life; while in other animals, though inferred to exist, it remains as yet unrecognized. This is the case, for instance, with the majority of crustacea, spiders, and insects. Judging from the instances in which an organ of hearing has been detected in mollusks, and in a very few representatives of the classes above named, it seems (however novel the information may be to many readers) that it is an organ of special sense which is not habitually, or even usually, found in the head, and in direct relation with one of the ganglia composing the brain. Further remarks, however, on this subject must be deferred until a brief description has been given of the nature and distribution of the nervous system in some of the principal groups of invertebrate animals.

These, then, are the commonly-received modes by which organisms are impressed from without, and by which they attune themselves to the conditions and actions in their medium. It was recognized by Democritus, and other ancient writers, that they are all of them derivatives, or more specialized modes of a primordial common sensibility, such as is possessed by the entire outer surface of the organism. Touch, taste, smell, vision, and hearing, are sense-endowments, having their origin in organs formed by a gradual differentiation of certain portions of the external or surface layer of the body—that is, of the part in

which common sensibility is most frequently called into play. And just as this common sensibility is a crude or general sense of touch, so are the several special senses only more or less highly-refined modes of the same sense-endowment. In the case of special tactile organs, of organs of taste and organs of smell, the several contacts between the animal and the body which impresses it, though differing in their delicacy or refinement, are still immediate; while in the case of the organs of hearing and the organs of vision the contact between the sensitive surfaces and the impressing body is mediate, by the intervention in the one case of vibrations transmitted through water or air, and, in the other, of vibrations from the often far-distant luminous body, through an intermediate and all-pervading ether.

The movements of locomotion, or of parts of the organism which become established in correspondence with these various impressions, slowly increase in number, definiteness, and complexity. Such responsive movements, however, are found, as a general rule, to have the effect of prolonging the action of any influences which previous individual or race experiences have proved to be favorable to the life and well-being of the organism; and, on the other hand, of cutting short or avoiding influences which past individual or race experiences have proved to be contrary to its general well-being. The capture and swallowing of food are ends to which a very large proportion indeed of the definite motions of most of the lower organisms are directed; and this direction of their energies is only a special case to be included under the rule above indicated; just as efforts to escape from predatory neighbors are other, though opposite, instances of the same rule.

In addition to the various modes of impressibility by external influence which we have hitherto been considering, there are certain internal modes of impressibility due to changes in the condition of internal parts of the organism. These are commonly spoken of as divisible into two categories: 1. The impressions derivable from, or in some way attendant upon, the contractions of muscles; and, 2. Impressions emanating from one or other of the various sets of internal organs, such as the alimentary canal and its appendages, the respiratory organs, the genital organs, or other internal parts.

With the first set of impressions we have at present nothing to do. They differ altogether from others, whether of external or internal origin, by the fact that they follow or accompany movements whose intensity they are supposed to measure, and do not themselves lead to movements. Granting that such impressions may have a real existence, it is obvious we can know nothing about them among invertebrate animals, if they have only a subjective existence, and do not cause an efflux of molecular movements along outgoing nerve-fibres.

The second category of internal impressions—those emanating

from the viscera—are undoubtedly very important in relation to animal life generally. In part they have the effect of causing contractions of related muscular portions of the viscera—as when the presence of food in certain portions of the alimentary canal excites impressions, followed by contraction whereby the food is propelled farther on. In part, however, they act upon the principal nerve-ganglia—those constituting the brain—and thus excite the external sense-organs with which they are connected to a higher order of activity. Visceral impressions may cause an animal eagerly to pursue food, or to be alert in discovering its mate; so that in these, and in many other instances, internal impressions, reaching the cerebral ganglia, would seem to excite a higher receptivity to certain kinds of external impressions and a corresponding readiness to respond on the part of the moving organs whose activity is related to such external impressions.

SCIENCE AND THE LOGICIANS.

By DAVID BOYD, A.M.

UNDER the above heading may be comprehended the most of what we are desirous of saying in review of the article entitled "Science and Religion," by Dr. Charles F. Deems, in THE POPULAR SCIENCE MONTHLY for February.

We first run counter to the author upon the definition of science taken from Sir William Hamilton's "Logic." Says he: "We can all afford to agree upon the definition rendered by the only man who has been found in twenty-two centuries to add anything important to the imperial science of logic. Sir William Hamilton defines science as a complement of cognitions having in point of form the character of logical perfection, in point of matter the character of real truth."

In the first place, Hamilton is not the only man since Aristotle that has been found to add anything important to logic. There has been a whole department, and by far the most valuable department of that science, brought into existence during the last three hundred years. We have reference to inductive logic, or scientific method. Hamilton had nothing to do with the creation of this department. His additions are wholly confined to the barren field of *formal* logic. The other department is the result of the joint labors of Bacon, Galileo, Newton, Herschel (John), Mill, Bain, and Jevons.

Hamilton's additions to formal logic consist chiefly in what is known as the quantification of the predicate, and the moods and figures consequent upon this. There is much difference of opinion as to the value of these additions. Mill and Bain affirm that by the quantification of the predicate no new or distinct meaning is conveyed,

nor is there even a more intelligent rendering of an old meaning. In our own opinion the distinction between the comprehension and the extension of propositions is important; but it is paraded with too much ostentation, and treated with too much prolixity. Hamilton's great virtue is his clearness of statement and exhaustiveness of treatment. His method is admirable. Sometimes, however, there is too much display of his own erudition.

But even in the domain of formal logic Hamilton is not the only one that has within the present century made important additions. Prominent among these is De Morgan. Especially valuable are his discussions upon the different values of the logical copula. Prof. Boole has also made important additions to the syllogism, and has most ably supported the theory of the common ground occupied by logic and the mathematics. Prof. Bain also, in pure logic, has made a most important generalization. Hamilton's three laws of thought, namely, identity, non-contradiction, and excluded middle, he has reduced to the single law or canon of consistency.

So much for the assertion that Hamilton was the only man in twenty-two centuries to make any important additions to the imperial science of logic. Like enough the doctor would exclude scientific method from the *imperial science*. Perhaps he regards formal logic alone fit to wear the purple. But even here we see that there can be no such claim set up. If, however, he could claim this distinction, it would afford no reason for receiving his definition of science without question. That should stand or fall wholly upon its own merits. The greatest of men are not without personal biases. It is well known that Hamilton had a metaphysical bias. In his work on metaphysics the first three lectures are occupied in attempting to prove the superiority of mental science over natural science. He quotes with much approval this ancient declaration, "On earth there is nothing great but man, in man there is nothing great but mind." This being his known bias, before examining the definition, an investigator of Nature, a believer in scientific method, might have thought that it was by no means certain that he "could afford" to take it simply on his authority. However, when we come to the definition itself, the *matter* of it is well enough. But we have the temerity to suggest that its *form* might be improved without changing the substance. It is too pedantic and prolix. It is not in a shape easily to be remembered. We would render it thus: Science is *real knowledge logically classified*. But, as Bain remarks, positive definition is not thorough enough. As he says in his second canon on definition, it is needful to assemble for comparison the particulars of the contrasting or opposed notion. We can never know distinctly what a notion is until we contrast it with its opposite. Knowing is discriminating. What is not science? What is the other notion that lies side by side with it—in contrast, but contained under the same genus? Now, if we

define science simply as knowledge or "complement of cognitions," it is contrasted with feeling or emotion. Its correlatives are productions designed to please, such as poetry, painting, or the fine arts generally.

If religion be regarded as proceeding wholly from the emotional nature, it may be contrasted with science and classed among æsthetic conceptions. But narrowing the definition further by qualifying knowledge by the terms "logically classified," we then have science as contrasted with or opposed to particular knowledge, or knowledge imperfectly classified. Qualifying further by placing the word *real* before knowledge, we have it contrasted with error or not genuine knowledge. By reading Hamilton, it will be seen that error is his antithesis to his *real* truth in the definition. But hypotheses are not error, since they are not held as truth. The distinguishing character of error is that, while false in fact, is is supposed to be true completely. Hypotheses are neither genuine truth nor errors, so long as they are held merely as such. They lie upon the border-lands of truth and error, and Hamilton's definition cannot banish them completely from the domain of science. They are properly allowed to hover around its borders. But we totally disagree with Dr. Deems as to the value of these "guesses" at truth. Says he, "A professor of religion has just as much right to guess as a professor of science, and the latter no more right than the former, though he may have more skill." Now, as to the right, there can be no dispute, but, as to the value of the guesses, this better *skill* makes all the difference in the world. Prof. Huxley is right in his estimate of guesses. Says he, "Do not allow yourself to be misled by the common notion that an hypothesis is untrustworthy because it is an hypothesis. What more have we to guide us in nine-tenths of the most important affairs of daily life than hypotheses, and often very ill-based ones? So then in science, where the evidence of an hypothesis is subjected to the most rigid examination, we may rightly pursue the same course. You may have hypotheses and hypotheses. A man may say, if he like, that the moon is made of green cheese; that is an hypothesis. But another man, who has devoted a great deal of time and attention to the subject, and availed himself of the most powerful telescopes, and the results of the observations of others, declares that it is probably composed of materials very similar to those of which the earth is made up; and this also is an hypothesis." You perceive that it makes a good deal of difference both as to who guesses and as to what is guessed. Indeed, so many scientific hypotheses have been verified in the face of the opposing theological hypotheses, that there begins to be a strong presumption in their favor before verification. Nor is it strange that we should be led to regard them as highly probable. The investigator of Nature, familiar with her processes and her laws, founds these guesses upon broad and deep analogies.

But we have only to follow the reverend doctor a few pages, until we find that hypotheses, so far from being extra-scientific, wholly make up our science. He mounts Hamilton's definition for the purpose of trampling upon scientific hypotheses. But, in his zeal for narrowing the sphere of science, he arrives at the remarkable conclusion that "all science is purely a classification of probabilities." He has at length kicked the definition completely from under him, and remounted a platform entirely composed of hypotheses. He, however, is careful not to say, "It is certain that there are no certainties." Still he leaves us wholly in the dark as to where may be found those "very few certainties" which it appears to him God has seen fit to show us, "more for the purpose of furnishing the idea than for any practical purpose." The God of the modern divine has still about him a touch of the jealousy of the Zeus of Æschylus. He would have chained to the rocks the modern seeker after hidden knowledge, the invader of his own domain of certainties.

We say that we are left completely in the dark as to where are to be found those few certainties which God has seen fit to show us as specimens. We are assured that they are not to be found in science. This is only classified probabilities. The "imperial science of logic" has been demolished with the rest. We wonder whether it is because science embraces only *real truth* that it is uncertain or probable, or is it owing to its methodical logical arrangement that it has acquired this character? He should remember that most people have faculties called memories, that last them through several pages of reading, and that there is a chance for mediate or remote contradictions to be detected.

Again, in his zeal to prove that all science and religion stand upon the common basis of faith, he overleaps himself, and gives us as the results of his logic, "*Ex nihilo geometria fit.*" So I suppose we may be allowed to say likewise, "*Ex nihilo religio fit.*" Is that what he started out to prove? No, it was only this very sensible proposition, that "we can acquire no knowledge by our logical understanding without faith in the laws of mental operations." This simply amounts to saying that we cannot consistently believe in the products of thinking except we believe in faculties of thinking. We suppose that no one doubts that. But believing that by no means involves the assumption that science or knowledge rests upon the same basis as religious faith. It is a very different thing to believe in our own experiences, feelings, sensations, observations, comparisons, memories, representations, etc., and to believe in certain fundamental religious dogmas, as, for example, "God is an infinite person." God is three infinite persons. The second of these three infinite persons, which all make one infinite person, is now sitting in heaven upon a throne on the right hand of the first infinite person, neither of which has any parts, but all three make one indivisible unity. Most men will con-

tinue to think that the above propositions differ very much from the two fundamental axioms of mathematics, "Equals added to equals and the sums are equal; and two things each equal to a third are equal each to each." In denying these, we must deny the laws of thought, the powers of the mind in distinguishing a thing from what it is not, or from that which it stands in contrast with, or in opposition to. All the other axioms of geometry, as Bain has shown, are either verbal propositions or can be derived from these, since subtraction is implicated in addition, multiplication derived from addition, and division implicated in multiplication.

The absurd conclusion at which the doctor arrives, namely, "*Ex nihilo geometria fit*," ought to show him that to begin with a metaphysical point was hardly the proper way to build up the science of geometry. Of course, it being nothing, the geometry that he constructed out of it, no matter how many intermediate propositions intervened, must be nothing. Suppose we try the analytic method of arriving at definitions. But first we are compelled to controvert the assertion that it is necessary to believe the three following propositions, or there can be no geometry, namely, that "space is infinite in extent, that it is infinitely divisible, and that it is infinitely continuous."

Now, I deny that geometry has anything to do with infinity; indeed, the doctor, before he gets through, says even more than this. "Science," says he, "has the finite for its domain, religion the infinite." What we have to do with in geometry is simply the relations of the *attributes* or *propria* of *definite extension*. But as *definite* extension has for its correlative *indefinite* extension, we need to understand it in a sort of general way. Experience furnishes us with the mutually-implicated notions of the contained and the containing, the bounded and the bounding. We cannot separate them completely in thought. The assertion of the one implicates the other. What lies without any extension is space—indefinite space. Simply that it is outside of our particular part of space is all that we have to do with it: whether it is infinite or not is none of the business of the geometrician. Indefinite extension, or the notion of space in general, is very different from the notion, if there be such a one, the words infinite space would connote. Indefinite space is comprehensible in the only sense that it needs to be comprehended, namely, as the correlative of extension or definite space.

This brings us to the genesis of the definitions of geometry. Experience makes us at first acquainted with extended bodies. This acquaintance goes no further than a knowledge of their attributes, or *propria*. All these properties come into the mind as a confused aggregate; it is not clearly perceived as a whole made up of distinct parts. The relation of part to part is perceived only in a vague and general manner. The work of the geometrician is to analyze these

parts, and to establish their exact relations. He compares, adds, subtracts, multiplies, divides. In order to communicate his knowledge of the relation of parts, he must use words; these words he must define, if their meaning is not obvious to the one instructed. But if the property is of a primary nature, and given in the experience of every one, there is no need of definition, and indeed no rational definition can be given. This is true alike of the notions, extension, surface, line, and point. Each of these is as much a *datum* of simple experience as the notion of white or blue; and it is just as absurd to attempt to define the one class of concepts as the other. They may be, however, brought out a little more closely by contrasting the correlatives in the manner that we have attempted with extension and indefinite space. Thus surface may be contrasted with the solid volume, or definite space, of which it forms the boundary; line with surface, of which it in turn is the boundary; and, lastly, point with line, of which it is the termination or the where of separation. It is not true that the existence of forms depends upon the motions of points. Forms are given in experience through sensation. A point is the ultimate step in the analysis of boundaries. It is sheer nonsense to attempt to construct lines out of points, surfaces out of lines, and volumes out of surfaces. All that it is necessary to say further upon this subject is, that the differentiæ of the higher mathematics are not nothings, but quantities the least conceivable. The least conceivable portion of a line is not a point; the least conceivable portion of a surface is not a line; the least conceivable portion of a volume is not a surface, for the simple reason that no portion of a thing can be its boundary.

Now, in conclusion, we say that geometry rests upon no affirmations in respect to the infinite, but, on the contrary, it is wholly occupied about the relations of the finite in space. We have the assurance from the doctor that the finite is the sphere of every science, while the sphere of religion is the infinite. This certainly would cast theology out of the sphere of science, for the doctor has laid down as one of its fundamental concepts, "God is an infinite person." Sir William Hamilton's definition, in its very first clause, also excludes theology from science, if we take himself as authority for the meaning of the term cognition. Every cognition is simply a perception of *relation*. The infinite and absolute—equal God—are not thinkable. Hence theology can have no "complement of cognition" out of which to classify a science.

In another place we find that the cry of conflict has its origin in confounding theology with religion. "Theology is not religion any more than psychology is human life, or zoölogy animal life, or botany plant-life. Theology is objective, religion is subjective. Theology is the scientific classification of what is known of God; religion is a loving obedience to God's commandments. Every religious man

must have a theology, but it does not follow that every theologian must have a religion. There may be a conflict between theology and some other sciences, and religious men may deplore it," etc. Now, in our opinion, if every religious man must have a theology, and if his theology be in conflict with science, he must either be in conflict in opinion with that science or abandon his theology. But the truth is, that the real, *actual* conflict arises from the religious element. The conflict of opinion is in the theology of a man; the conflict, as it appears upon the stage of the world's history in acts and deeds, has sprung from the religious nature, even as defined by Dr. Deems. A man may hold what theological views you please and make no disturbance in the world, provided he does not think much about his duty in obeying the commands, word, or will of God, all of which are a part of his theology. For instance, one of the commands of God, as contained in his word, and to which he should render a "loving obedience," is "Suffer not a witch to live." Now, a man may believe in that command simply as a dogma, but, being indifferent in the matter of rendering a loving obedience, he will not let it influence his conduct, and so will make no effort to hunt up and have witches burnt. If, on the contrary, he has a loving obedience to God's word, he will trample upon every kindly feeling and instinct of his nature rather than not have the command carried out.

Accordingly, we find that it has been the pious, the sincere, the believers in duty, those wishing to render a loving obedience to God's word, or what they thought was his word, who have in every age been the persecutors. But you say that they were acting under a delusion. They mistook what was the word of God. But how are they to know what is his word, if direct commands like the foregoing are not his? Besides, if there was a mistake, it was in their theology, and not in their religion; that only impelling them to lovingly obey God's commands as they knew them. Religion is but an impulse, a blind instinct. It knows nothing about weighing and comparing opinions. Theology furnishes it with these. If these are bad, its conduct will be bad; if good, the conduct will be good. All it knows is blind obedience—zeal to do the will of God as it knows it; and the pretended science, which alone can give it guidance, is a science of the Unknowable, the Infinite, the Absolute.

We will close with a quotation from Lecky's "History of Rationalism," in reference to Luther: "He was subject to many strange hallucinations and vibrations of judgment, which he invariably attributed to the direct agency of Satan. Satan became, in consequence, the dominating conception of his life. In every critical event, in every mental perturbation, he recognized satanic power. Fools, deformed persons, the blind and the dumb, were possessed by devils. Physicians, indeed, attempted to explain these infirmities by natural causes; but those physicians were ignorant men—they did not know all the

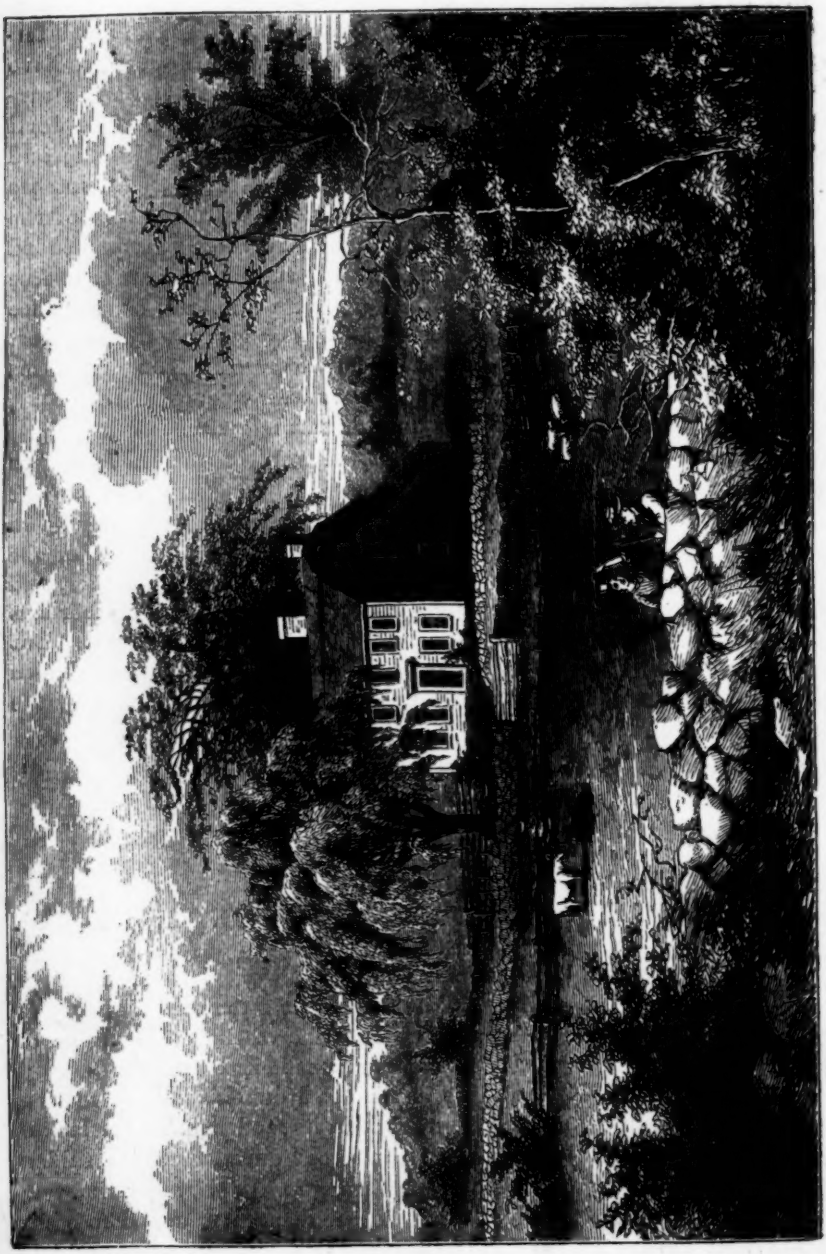
power of Satan. Every form of disease might be produced by Satan or his agents, the witches; and none of the infirmities to which Luther was liable were natural; but his earache was peculiarly diabolical. Hail, thunder, and plagues, are all the direct consequence of the intervention of spirits. Many of those persons who were supposed to have committed suicide had in reality been seized by the devil and strangled by him, as the traveler is strangled by the robber. The devil could transport men through the air. He could beget children; and Luther himself had come in contact with one of them. An intense love of children was one of the most amiable characteristics of the great Reformer; but on this occasion he most earnestly recommended the reputed relatives to throw the child into the river, in order to free their house from the presence of the devil. As a natural consequence of these modes of thought, witchcraft did not present the slightest improbability to his mind. In strict accordance with the spirit of his age, he continually asserted the existence and frequency of the crime, and emphatically proclaimed the duty of burning witches."

We see what a loving obedience to the word of God led Luther to recommend. That this spirit has died out, is wholly due to the advancement of science and rationalism, and not to any change in the religious spirit *per se*, or to any different interpretation of the Bible. The witchcraft is there, as it was in the days of Luther, and the injunction not to suffer witches to live is there, and neither has been explained any better than it was in the middle ages. But the researches of the investigators of Nature have gradually driven these notions out of the minds of men, and stamped them with the opprobrium of absurdities.

GREELEY, COLORADO, *February* 14, 1876.

SKETCH OF BENJAMIN THOMPSON (COUNT RUMFORD).

IN his late work, "Recent Advances in Physical Science," Prof. Tait, of the University of Edinburgh, has attempted a history of dynamical science, or rather of the doctrine of the conservation of energy. Though this great doctrine is recent in its completer development, Prof. Tait holds that it is implied in Newton's laws of motion, and that Newton only failed to grasp it in its modern form for lack of certain experiments. Where Newton broke down, there the subject remained for more than a hundred years, no physicist appearing who could take up the research at that point and carry it on. Prof. Tait says that "what Newton really wanted was to know what becomes of work when it is spent in friction." The experiments thus needed to open the way to a new era in the doctrine of forces were supplied



BIRTHPLACE OF BENJAMIN THOMPSON, IN NORTH WOBURN, MASSACHUSETTS.

by a self-educated American, the subject of this sketch. The newspapers say that he is dropping out of memory in this age, and was in his day a distinguished smoke-doctor and improver of fireplaces; but in the scientific world his fame has been increasing in recent years, and is destined to grow brighter with the further progress of physical knowledge. As attention has latterly been drawn to what America has done for science, it is desirable to give an account of the career and labors of this eminent American investigator.

Benjamin Thompson was born March 26, 1753, in Woburn, Massachusetts. He first saw the light in the west end of a substantial farmhouse, which is still standing a few rods south of the meeting-house in North Woburn. The dwelling is said to be well preserved, retaining its external and internal appearance unchanged, notwithstanding its great age, and it has been recently purchased by the citizens of Woburn, to be preserved as an object of public and historical interest. His father died in his infancy, and when the child was three years old his widowed mother was married to Josiah Pierce, Jr., of Woburn. His latest biographer, Mr. George E. Ellis, says that the lad "indicated from his early years an inconstancy and indifference to the homely routine tasks and the rural employments which were required of him, while at the same time he exhibited an intense mental activity, a spirit of ingenuity and inventiveness, and was found seeking for amusement in things which afterward proved to lead him to the profitable and beneficent occupations of his mature life. He showed a particular ardor for arithmetic and mathematics, and it was remembered of him afterward that his play-time and some of his proper work-time had been given to ingenious mechanical contrivances, soon leading to a curious interest in the principles of mechanics and natural philosophy."

He received the rudiments of a common-school education, and his guardians, finding that he was unfit for a farm-drudge, apprenticed him at thirteen to a merchant in Salem. While thus engaged, with such spare time and private assistance as he could get, he studied algebra, trigonometry, astronomy, and even the higher mathematics, so that before the age of fifteen he was able to calculate an eclipse. At sixteen he was sent to Boston to continue the dry-goods business, and there attended an evening French school. In 1771 he began the study of medicine with Dr. John Hay, of Woburn, and at the same time attended a few lectures at Cambridge. He taught school for a short time at Bradford on the Merrimack, and afterward taught in an academy in Concord, New Hampshire, higher up the same river, a town which had been formerly known as Rumford.

"When Benjamin Thompson went to Concord as a teacher he was in the glory of his youth, not having yet reached manhood. His friend Baldwin describes him as of a fine manly make and figure, nearly six feet in height, of handsome features, bright blue eyes, and dark au-

burn hair. He had the manners and polish of a gentleman, with fascinating ways, and an ability to make himself agreeable. So diligently, too, had he used his opportunities of culture and reading, that he might well have shone even in a circle socially more exacting than that to which he was now introduced. We may anticipate here the conclusion to which the review of his whole career will lead us, that, as boy or man, he was never one to allow an opportunity of advancement to escape him." At Concord, when nineteen years of age, Mr. Thompson married Sarah Walker Rolfe, a wealthy widow, aged thirty-three, and by whom he had a daughter.

The Revolution was now fermenting, and alienations and discords were springing up among the people. Young Thompson had made the acquaintance of Governor Wentworth of New Hampshire, who, discerning his genius and promise, gave him the military commission of major. This aroused a bitter feeling of jealousy not only in the subordinate officers over whom he had been sprung, but also with his superiors, who were all turned into effective enemies. His independent manners, his intimacy with the royal governor, and, perhaps, inconsiderate words in a time of excitement, led to the suspicion and the charge that Thompson was unpatriotic and sided with the royalists. By the potency of gossip and tale-bearing he was brought under suspicion of Toryism, and threatened with that dignified discipline of outraged patriotism, tar and feathers and riding on a rail. Thompson indignantly denied the accusation. He called for proof, and a meeting of his townsmen was called to consider his case. But no evidence of any kind was produced against him. Nevertheless the adverse feeling in Concord was so strong that he found it necessary to leave. There can be little doubt of the brutal injustice with which Thompson was treated. His biographer writes with evident impartiality, and presents the case in all its aspects, and, admitting that nothing bearing the character of evidence was to be found against his patriotism, hes ays that "Major Thompson insisted from the first, and steadfastly to the close of his life affirmed, that he was friendly to the patriot cause, and had never done or said anything which could be truthfully alleged as hostile to it." The simple fact seems to be that while young Thompson entertained, and probably expressed, his doubts about the issue of a conflict with the mother-country, as many other independent-minded men must have done, he was nevertheless in sympathy with the patriot cause, and was not only willing to devote himself to it, but earnestly sought the opportunity by petitioning the Provincial Congress for a position in the army. But he was defeated through the machinations of the officers who resented his appointment by Wentworth. His biographer says: "He lingered about the camp. He devoted himself zealously to the study of military tactics. He continued his experiments on gunpowder. He strolled between Woburn, Medford, Cambridge, and Charlestown, learning whatever

his inquisitive mind could appropriate. But there was one set of men whom he never could conciliate, who mistrusted his purposes, and cast upon him lowering looks as they met him about the camp. These were the general and field officers from New Hampshire, who looked upon him as a dandy and an upstart at least, if not also at heart a traitor. They would not associate with him, still less confide in him." It is further stated on authority, that there is no reason for doubting that "after the battle at Charlestown, Thompson was favorably introduced by some officers of Cambridge to General Washington, who had just assumed the command; and that, had it not been for the opposition of some of the New Hampshire officers, he would have had the place in the American artillery corps which was given to Colonel Gridley." The genius of Thompson was thus lost to the American cause through the rivalries and hatreds of army officers, a source of evil which profoundly troubled the life of Washington during the Revolution, as it did also that of Lincoln during the civil war.

Nothing was therefore left to Thompson but to remain in obscurity at home under a cloud of suspicion that would have darkened his life, or to seek a field of action elsewhere. He was a man of high spirit and great force of character, and of course would not submit like a poltroon to the degrading alternative. He accordingly took service under the government of his early allegiance. He went to England, and soon after his arrival, at the age of twenty-three, was given an appointment in the colonial office, under Lord George Germaine. He directed immediate attention to military matters; improved the accoutrements of the Horse-Guards; continued and extended his experiments on gunpowder, and improved the construction of firearms. He experimented with great guns, made a study of the principles of naval artillery, and devised a code of marine signals. He also made investigations into the cohesion of bodies, which he communicated to Sir Joseph Banks, President of the Royal Society, and was elected Fellow of that body in 1779 at the age of twenty-six. He very soon became one of the most active and honored members of the Royal Society, always attending its meetings when he was in London. He afterward received a colonelcy from the British Government, and came back to this country in command of a regiment on Long Island, building a fort at Huntington. He returned to England in 1783, and the same year made a tour on the Continent. At Strasburg he accidentally met with Prince Maximilian of Deux Ponts, then field-marshal in the service of France, who became so interested in Colonel Thompson that he gave him an introduction to his uncle the Elector of Bavaria at Munich. The Elector was a man of liberal views, and discerning in Thompson the talent that he thought might be made available in promoting the interests of his government and people, he made overtures to him to enter his service in a joint military and civil capacity. The

proposition was favorably received, but, as Colonel Thompson was a half-pay officer of the English crown, he needed to have the permission of the king before making a Continental engagement. He therefore returned to England in 1784, and received not only the king's permission, but also the honor of knighthood and the continuance of his half-pay, and he returned to Munich the same year as Sir Benjamin Thompson. A splendid field was now before him, and he entered upon a series of the most remarkable labors, to which he devoted himself with great assiduity. "These labors ranged from subjects of the homeliest nature in their bearings upon the thrift, economy, and comfort of life for the poorest classes, through enterprises of wide-extended and radical reform, and comprehensive benevolence, up to the severest tests and experiments in the interests of practical science." . . . . "The elector was from first to last his constant friend, never thwarting him, never holding back his aid; but, on the contrary, ready always to advance every plan of his, and to espouse his views when questioned or opposed by other counselors."

It is impossible, in this brief sketch, even to enumerate the extensive and important measures of public beneficence and social amelioration which Sir Benjamin projected and successfully carried out. He reorganized the entire military establishment of Bavaria, introduced not only a simpler code of tactics and a new system of order, discipline, and economy, among the troops and industrial schools for the soldiers' children, but greatly improved the construction and modes of manufacture of arms and ordnance. He devoted himself to various ameliorations, such as improving the construction and arrangement of the dwellings of the working-classes, providing for them a better education, organizing houses of industry, introducing superior breeds of horses and cattle, and promoting landscape-gardening, which he did by converting an old abandoned hunting-ground, near Munich, into a park, where, after his departure, the inhabitants erected a monument to his honor. He moreover suppressed the system of beggary, which had grown into a recognized profession in Bavaria and become an enormous public evil—one of the most remarkable social reforms on record. Mendicity in Bavaria was at that time "a stupendous and organized system of abuses, which, gradually growing upon the tolerance of the government and people, had reached such proportions and had established itself with such a vigorous power of mischief as to be acquiesced in as irremediable. Beggars and vagabonds, the larger part of whom were also thieves, swarmed all over the country, especially in the cities. These were not only natives, but foreigners. They were of both sexes and all ages; they strolled in all directions, lining the highways, levying contributions with clamorous demands, entering houses, stores, and workshops, to rob, interrupting the devotions of the churches with their exactions, and extorting everywhere, through fear, what they failed to get by

importunity. These swarms of mendicants and freebooters were in the main composed of strong, healthy, and able-bodied persons, who preferred an easy life of indolence to any kind of industry. They had become the terror and scourge of the country. They would steal, maim, and expose little children, and compel them to extort, by their piteous appeals, a fixed sum for a day's gatherings, with the threat of an inhuman punishment if they failed. Every attempt to suppress this system of outrages having been thwarted, the community had learned to submit and conform to it as admitting of no relief; and this wretched tolerance seemed to double the number of these vagabonds, while it raised beggary into a profession." So systematic and rooted had this state of things become that "the beggars formed a caste in the cities, with professional rules, assigning to them beats and districts, which were disposed of by regulations, in case of the death, promotion, or removal, of the proprietors.

Sir Benjamin resolved upon the extirpation of this system, and the conversion of this lazy and dissolute class into thrifty, self-sustaining laborers. His policy was cautious, deliberate, and wise. He knew exactly what he wished to do, made ample provision for it, and secured the coöperation of the influential classes in the execution of his plan. We cannot describe it here, but its success was complete. The beggars were swept from the streets, cared for, soon set to work, and raised to a condition of self-respecting industry. So effectual was the work that Sir Benjamin won the heart-felt gratitude of the very class upon which he had operated. This is beautifully illustrated by the fact that, "on one occasion, when he was dangerously ill, the poor of Munich went publicly in a body to the cathedral and put up public prayers for his recovery. And again, when, four years afterward, they learned that he was in a similar condition at Naples, they of their own accord set apart an hour each evening, after they had finished their work in the military workhouse, to pray for him."

For the valuable services rendered in Bavaria Sir Benjamin received many distinctions, and, among others, was made Count of the Holy Roman Empire. On receiving this dignity he chose a title in remembrance of the country of his nativity, and was henceforth known as Count of Rumford. His health failing from excessive labor, and what he considered the unfavorable climate, he came back to England in 1798, and had serious thoughts of returning to the United States, having received from the American Government the compliment of a formal invitation to revisit his native land. While in England, Count Rumford organized the Royal Institution of Great Britain in 1800, which was designed for the promotion of original discovery and the diffusion of a taste for science among the educated classes. Its success has more than vindicated the sagacity of its founder. He afterward returned to the Continent, and, while frequently visiting Munich, took up his residence in Paris. In 1805 he married the widow of the

celebrated French chemist Lavoisier, who was beheaded in the French Revolution. The union, however, not proving a happy one, they soon separated, and Rumford died in his residence at Auteuil the 21st of August, 1814. His first wife had died in 1792, and his daughter, who inherited his title, had come to him at Munich, and returned to America after her father's decease.

The philanthropic interest of Count Rumford in the poor and defective domestic life of the lower classes of society had a great influence in determining the course of his scientific inquiries. It was this feeling that led him to investigate the properties and domestic management of heat. He determined the amount of it arising from the combustion of different kinds of fuel, by means of a calorimeter of his own invention. He reconstructed the fireplace, and so improved the methods of warming apartments and cooking food as to produce a saving of from one-half to seven-eighths of the fuel previously consumed. He improved the construction of stoves, cooking-ranges, coal-grates, and chimneys, and showed that the non-conducting power of cloth is due to the air inclosed among its fibres; and he first pointed out that mode of action of heat called convection; indeed, he was the first clearly to discriminate between the three modes of propagation of heat—radiation, conduction, and convection. He determined the almost non-conducting properties of liquids, investigated the sources of the production of light, and invented a mode of measuring it. He was the first to apply steam generally to the warming of fluids and to culinary operations. He also, as has been stated, experimented extensively upon the use of gunpowder, the strength of materials, and the maximum density of water, and made many valuable and original observations upon an extensive range of subjects, which are described in the essays recently for the first time published in a complete form. As Prof. J. D. Forbes remarks, "all Rumford's experiments were made with admirable precision, and recorded with elaborate fidelity and in the plainest language. Everything with him was reduced to weight and measure, and no pains were spared to obtain the best results."

But it was his investigations concerning the nature of heat that will make him immortal. By experiments in boring cannon he proved its immateriality, and that it does not consist of an imponderable substance or fluid, as implied by the old theory of caloric. In these experiments he demonstrated that the heat generated by friction does not come from any latent source in the materials used, but is derived from the power spent in producing the friction; that its amount is in the ratio of the power expended; that it is a case of the transformation of energy, and a mode of molecular motion. He was half a century in advance of his age, and his researches were long unappreciated; but they are now recognized as forming an epoch in the progress of physical science.

CORRESPONDENCE.

"WHAT CONSTITUTES RELIGION?"

To the Editor of the Popular Science Monthly.

DEAR SIR: The use of my name twice in your notice of Mr. Fiske's new work on "The Unseen World," in your May number, perhaps justifies me in soliciting a small space for comment on some expressions in that notice.

You are defending Dr. Draper from Mr. Fiske's trenchant attacks. To that there can be no objection. Confederates are justified in standing by one another; but I do not think that you are justified in saying that "the point of contention is as to what constitutes religion." So far from there being contention on that point, there is really no important difference. All "sects," no matter how much they "eat each other up in their denial of dogmas," as you affirm, agree as to what religion is. It does not seem edifying to behold in you the temper which dictates the first of the following sentences, although the exceeding generosity of the careful proposal in the second has a redeeming flavor. "We hope that the agreement of Messrs. Brownson, Hill, Washburn, Deems, Fiske & Co., in denouncing the groundlessness of the 'conflict,' will not be construed as implying any agreement among the parties as to what religion is. If these gentlemen will get together and settle the point, an important step will be gained, and THE POPULAR SCIENCE MONTHLY will gladly pay the expenses of a convention of reasonable length for such a purpose; but we stipulate not to foot the bills until they reach an agreement."

For the other gentlemen I cannot answer, but I simply say that I never did "*denounce* the groundlessness of the conflict," but have announced it and endeavored to demonstrate it, and you are witness that I am "vehement in *asserting* the groundlessness and absurdity of Dr. Draper's assumption" of the conflict (page 118).

Why are you so anxious to keep your readers from believing that the gentlemen whose names you have recited in fact do not and really cannot agree as to what is "religion?" Have you ever seen anything in our writings or heard anything in our oral teachings to justify the supposition that we do not agree? As you challenge us, I accept the challenge for my part. I will not expose you to the cost of a convention, but here, in my study, without consultation with any of the other gentlemen you name, I venture to give two definitions of religion, in both of which I venture to predict that all those gentlemen, if they see this letter, will heartily agree, and that these definitions will win the assent also of Archbishop McCloskey, Bishop Potter, Bishop Foster, Bishop Wightman, Chancellor Crosby, Rev. Dr. Armitage, and Rev. Dr. Storrs, representatives of the leading "sects."

To give the least first, here is my own definition: Religion is *loving obedience to God's will.* No matter how or where that will is discovered, nor what it is, he is a religious man who does what he believes will please God, because he loves God.

The second is authoritative. It is that of St. James (i. 27): "True religion and undefiled before God and the Father is this: To visit the fatherless and widows in their affliction, and to keep himself unspotted from the world." A life of inward purity and outward beneficence is a religious life.

I venture to think you may pass these around the whole circle of religionists and find unanimity. But do not we religionists disagree? Certainly. The five gentlemen you have mentioned, and the seven whom I have named, differ more or less, oftener more than less, and on some points apparently irreconcilably. But mark: we never differ in our religion; it is in our science. The moment two men become scientific, whether they are religious or not, they begin to "eat each other up in their denial of dogmas." So long as we keep to religion, we are one. Our *hearts* are together. It is only with our *heads* that we butt one another. I have worshiped God in company with each of the seven distinguished clergymen whom I have ventured to name, and yet there is not one of them who does not hold some dogma of doctrine or ecclesiasticism to which I cannot subscribe. As religionists, we agree. As scientists, we differ. It is on the ground of our theology that we differ, and that is purely a scientific ground. Be pleased always to remember that theology is only a science like geology or biology.

But, my dear sir, we theologians would be out of fashion if we did not "eat each other up in our denial of dogmas." All *other* scientists do. The dogma of heterogenesis tries to "eat up" the dogma of homogenesis, while the dogma of pangenesis is fairly bursting itself to swallow both the others bodily; and there is no small conflict between spontaneity and heredity,

and meanwhile biosis is striving vigorously to hold its ground against archebiosis.

Behold! are not Religion and Life the two greatest subjects? You are quite anxious that your readers shall fancy that religionists cannot agree in their definitions of religion. But you do not show them that even on the subject of Life the scientists are greatly at difference. Prof. Owen says that "Life is a sound;" Schelling says it is a "tendency." Herbert Spencer calls it "a continuous adjustment." Dr. Meissner says it is "but motion." Dr. Bastian holds that he has produced plants and animals from inorganic matter. Schultz positively believes it never was done and cannot be done: and Prof. Huxley holds that "constructive chemistry could do nothing without the influence of preëxisting living protoplasm."

I do not wish to crowd your pages, and so content myself with these few instances out of the multitudes of conflicting and perplexing differences among "advanced thinkers."

Even you, my dear sir, have not utterly escaped. You once wrote, "If the forces are correlated in organic growth and nutrition, *they must be* in organic action." Manifestly, after that sentence was written, you meditated, and, meditating, you discovered that the *sequitur* was not quite as apparent as it ought to be. You did not strike out the sentence, but you apologized for it handsomely by saying, "From the great complexity of the conditions, the same exactness will not be expected here as in the inorganic field." But you see, my dear sir, that theology is a science which has for its field those subjects in which there is the greatest complexity of conditions, and you must not demand of your brother scientists as much exactness in the statements of a metaphysical proposition as you may in the statement of the length of a fish's tooth.

But as to your statement that *the forces must be correlated in organic action*, are you not in danger of being "eaten up" by the statements of your friends, Bastian, Barker, and, what is still harder on you, Herbert Spencer? Prof. Barker teaches that the correlation of the natural forces with thought "has never yet been measured." Then, it is a mere "guess." Dr. Bastian says that it "cannot be proved" that sensation and thought are truly the direct results of molecular activity. Then it is a mere "guess." Mr. Herbert Spencer, whose name is conclusive authority with you, and who, I am most frank to admit, knows as much about the "unknowable" as any writer whose works I have read, says that the outer force and the inward feeling it excites "do not even maintain an unvarying proportion." Then it is a mere "guess." And, my dear sir, I do most heartily agree with your statement, "not he who *guesses* is to be esteemed the true discoverer, but he who *demonstrates* a new truth."

Now, if Messrs. Spencer, Barker, Tyndall, Huxley, Büchner, Draper, Youmans, "& Co.," will "get together and settle" what Life is, or Thought, "an important step will be gained;" and, not to be outdone by your generosity, I will engage to "pay the expenses of a convention of reasonable length for such a purpose," but I "stipulate not to foot the bills until you reach an agreement."

Trusting that both you and I, as we grow older, may have more science and more religion, and room enough in our heads and hearts for both without "conflict,"

I am, very faithfully, your co-laborer,

CHARLES F. DEEMS.

Of course Dr. Deems meant to announce, assert, and declare, the groundlessness of the conflict between Religion and Science; and we think the readers of our article which he criticises were not in the slightest danger of misapprehending his position, notwithstanding the slip of writing in which he is said to have *denounced* it.

Dr. Deems asks: "Why are you so anxious to keep your readers from believing that the gentlemen whose names you have recited in fact do not, and really cannot, agree as to what is religion?" Has not the doctor here slipped also, in inadvertent haste, and does he not really mean, Why are you so anxious *to make your readers believe*, etc.? and to this we reply, that the anxiety in regard to a definition of religion has not originated with us. It is the reviewers of Dr. Draper who have called for a definition of religion from him, and condemn his book as dealing with a "conflict" existing only in his own imagination, because he has not defined what religion is. Had he undertaken this, they tell us, it would have at once appeared that there is and can be really no such conflict. We said that "the point of contention is as to what constitutes religion," because the theological reviewers of Draper charge that what he treats as religion, and as conflicting with science, is not religion. We have not denied that religion can be so defined as to avoid all antagonism with science; and there is hope that the time may come when such a definition will be accepted and the antagonism will disappear. We only maintain that in the historic past,

with which Dr. Draper deals, such an interpretation of religion had not been reached, and that it is very far from being arrived at at the present time. Dr. Draper has been reproached for not defining religion; had he done so, and had his definition described that which has passed under the name of religion, and been held as religion, generation after generation, his definition would have been at once repudiated by the theological party. We said that those who agree in demanding a definition of religion from Dr. Draper, and condemn his book as treating of an illusive conflict because he does not furnish it, cannot themselves agree upon the definition they profess to so much desire. Does Dr. Deems accept Mr. Fiske's definition? And if there is one definition, clear and complete, which all men can adopt, why does he bring us two, and which are we to accept? They are certainly not identical, for one makes it consist in a special relation of man to God, and the other in charity and moral purity. Dr. Deems defines religion as "loving obedience to God's will;" but if the obedience is inspired by Calvinistic fear, is it religion or not? Loving obedience to God's will—but how ascertained? Dr. Deems may say, with broad liberality, either by the study of God's printed word, or by the study of his living works; but can he insure us an agreement among all parties upon this basis? From the doctor's position, that religious people disagree among each other on account of their science, we respectfully dissent. Science is not an agency of discord, but of concord. There are undoubtedly disagreements in science, for its nature is progressive, and diversities of view are inevitably incident to its imperfect stages. Yet the great law of scientific thought is that, with the progress of investigation, there is ever a tendency to wider agreement, until its truths at length become established and universally accepted. Throughout civilization it is in science, and, we might almost say, in science alone, that men are brought into essential agreement. Through the power it has conferred over the elements of Nature have come the marvels of modern international communication and intercourse; and through the truths it has established in the domain of experience has come a body of common belief, which men of all languages, religions, and nationalities, can accept, so that we must regard science as in fact the predominant unifying agency of the world. The reason is, that it deals with the order of Nature, which is constant and ever open to observation and research. New questions are, of course, constantly arising in science, upon which there are at first wide contrasts of opinion, but the history of science abundantly shows, either that such questions are gradually cleared up, or, if this is found to be impossible—if the truth cannot be determined about them—then there comes agreement in this, and they are finally put aside as insoluble, and therefore questions with which science has no legitimate concern. Conflicting views now prevail on the problems of the origin of life and the nature of life, and time alone can determine what will be the issue of these inquiries; but we submit that these diversities of opinion are of a quite different kind from those between the Unitarian and the Trinitarian—the Universalist and the Perditionist.

EDITOR'S TABLE.

WHO SHALL STUDY THE BABIES?

THE reader's attention will be arrested by the novelty of our first article, by a distinguished literary Frenchman, giving the result of his observations on the progress of an infant in learning to talk. We confess to some mortification at seeing the name of a man at the head of such a discussion. Not that the dignity of M. Taine is at all compromised, for he never undertook a more important or a more distinguished task than critically noting the steps of mental evolution in a baby. Nevertheless, this would seem to be preëminently the proper work of woman—a work to which we might infer she would be drawn by her feel-

ings, in which she would be interested by her curiosity, and would take up from the temptation of her special opportunities. Yet M. Taine found that it had not been done. He wished to test Max Müller's views in regard to the genesis of language, and wanted a series of observations of infantine mental growth for the purpose. But they had not been made, the facts were wanting, and nothing remained but to make the study himself. We say this kind of work belongs to woman, and she is perfectly competent to peform it. Why, then, has it not been undertaken, and why has there not grown up a body of carefully-observed and widely-verified facts regarding psychological development in infancy such as would be valuable for arriving at inductive truths for guidance in the rational education of childhood? Undoubtedly, psychology is a backward science, imperfect from the obscurity and complexity of its questions, and its long cultivation by unscientific methods. But the value of observations upon the mental unfolding of infancy is not, by any means, dependent upon the possibility of immediately explaining them. Such observations, if accurately made and intelligently recorded, will have a value of their own independent of the state of psychological science, while they would become a permanent and potent means of its advancement. In most other fields of natural phenomena the facts are far in advance of the theories by which they are organized into science; in the field of mental growth, however, observations are scanty and speculation superabundant.

We are, of course, not to expect that things will come before they are wanted, and, if such observations are not called for, why should they be supplied? But the facts have been long and loudly called for, if not by psychologists, then by practical educators, while woman has had exclusive charge of the education that begins in infancy. She is an educator as a mother, and the culture of childhood has almost universally fallen into her hands as a teacher. We might surely have expected that, with their great excess of opportunity, some few women of ability would have gone carefully and critically and often over the ground which M. Taine has passed over once with such interesting results. But the work that might have been expected, so far as we are aware, has not been done, nor is there any promise of it. The difficulty is, that there has been nothing in woman's education either to interest her in the subject or to qualify her for dealing with it. Observations, to be valuable for scientific purposes, involve an accuracy of perception and an intellectual discrimination which are not to be had except by patient and methodical training of the observing powers. This is the one thing that has not been included in female education. Neither languages, nor mathematics, nor history, nor mental philosophy, nor music, nor general literature, affords any exercise whatever of the observing faculties. A student may become proficient in all these branches, while the intellectual interest in the phenomena of daily experience, and the objects of common life, remains as dormant as it is in the savages. Nay, more, absorption in these modes of mental activity, which involve chiefly the memory and reflective powers, is fatally unfavorable to observation, as it brings the mind under the control of mental habits that exclude it. No woman can make valuable observations on mental progress in infancy that has not had a culture fitted for it, first, by a long practice, such as she gives to music, in independent observation in some branch of objective science, as botany, for example; and, secondly, by a thorough knowledge of the constitution of the child, especially the functions of its nervous mechanism. With their heads filled with history, æsthetics, algebra,

French, and German, they will never attain to these qualifications for studying the character of children. The seminaries do not prepare them for it; the high-schools and the normal schools do not confer it. Nor is this all, nor the worst. There is no appreciation of it or aspiration for it. The so-called woman's movement, which professes to aim at her higher improvement and the enlargement of her activities, is not in this direction. It looks to public, professional, and political life, as woman's future and better sphere of action. In the new colleges for women that are springing up in all directions with munificent endowments, the supreme consideration seems to be to ignore sex, and frame the feminine curriculum of study on the old masculine models, and keep it up to the masculine standards. The spirit of these schools is that of a slavish imitation. They are organized with no reference to the urgent and living needs of society, but they go in for the traditional trumperies of the old colleges; and, instead of studying science in its personal, domestic, and social bearings, the women demand Latin and Greek, and as much of it as the masculine intellect has proved capable of surviving. Children are imitators. Savages are imitators. What else are the women in their demands for new and ampler opportunities of culture? They will study classics, and let the men study the babies; but, if they are incompetent, of course the men *must* do it. For this business of studying the science of infancy must be pursued by somebody, thoroughly and exhaustively. It is nothing less than a transcendent problem of human character lying at the foundation of the social state; for only as the human being is understood in its deeper organic laws, prenatal and infantine, as well as in its subsequent unfolding, can we arrive at settled and scientific views regarding the rights, claims, duties, and true interests of the individual in society. If not a new research, it is at least a new impulse and stage of research, and we say again that we should think intelligent and ambitious women would be glad to have a share in it, and would have wisdom enough to include it in their extended schemes of female education.

ENGLISH PHILOSOPHY IN GERMANY.

We not long ago called attention to a newspaper article under the title of "German Darwinism," which made a point against Herbert Spencer as not being recognized in Germany. We pointed out various reasons in the national habits of thought, why Spencer's doctrines, which are put forth under the form of a philosophical system, would be likely not to attract the attention of German thinkers so early as those of other Continental countries. Our view has since been strikingly confirmed by an eminent German authority, Prof. Wundt, of the University of Leipsic, a physiologist and psychologist of world-wide reputation. In a review of the German translation of "First Principles," published in the Jena *Literary Gazette*, Prof. Wundt gives an excellent account of the book, from which the following statements are condensed:

"Of living English philosophers Herbert Spencer undoubtedly stands in the foremost rank, yet his works have hitherto been little known in Germany. It would, however, appear that this neglect is soon to be retrieved, for, simultaneously with the appearance of the work under review, two other volumes by the same author are issued. By giving an excellent translation of 'First Principles' (under the title of 'The Bases of Philosophy'), Dr. Vetter has rendered good service to his countrymen, and it is to be hoped that he will further aid in making this distinguished author known in Germany by translating the subsequent volumes of his system."

"In the whole tenor of his views Mr. Spencer differs widely from the speculative philosophers of Germany. The indomitable persistency with which for twenty-five years he has worked on the various branches of science, bringing them into one system, has no parallel in Germany, save, perhaps, in Hegel's 'Encyclopædia.'"

"Among the dominant ideas in this sys-

tem the doctrine of evolution is preëminent. In Spencer's mind evolution is not merely a principle in biology, but extends on the one hand to inorganic Nature, and on the other hand to the domain of psychology and sociology. And here we take occasion to remind the reader that, independently of the stimulus given to scientific thought by Darwin, Mr. Spencer early recognized the importance of the law of evolution, to which from the first he gave very wide scope, and which he has illustrated with a multitude of original ideas."

"A detailed criticism of the 'First Principles' would necessarily require a book for itself, more especially because the German reader, from the very nature of his philosophical training, will enter on the study of the most general laws of being, the demonstration of which is the aim of the present work, with prepossessions different from those of the English author. Perhaps in the philosophical literature of recent times there is no English work which bears the national stamp so visibly as does Spencer's. From this point of view alone, to say nothing of the many pregnant thoughts it contains, it well deserves the attention of German readers. John Stuart Mill, in the philosophical direction of his mind, came too much under the influence of the French, particularly of Comte. Spencer's mind is, no doubt, more original than Mill's, and more free from foreign influences, though inferior in the splendor of external form. In all the philosophical speculations of Spencer we plainly see that practical sense which makes its way through the most difficult problems by the shortest route."

"Finally, though the German reader will find in these 'Bases of Philosophy' much that he will object to, and though on the capital points of the system he will dissent from the author oftener than he agrees with him, nevertheless he will not lay the book aside without having received many a valuable suggestion. Indeed, it may be truly said of works on philosophy, that we learn more from those which arouse our opposition than from those which merely echo our own opinions."

THE RUMFORD MEDALS.

THE Rumford gold medal of the American Academy of Arts and Sciences, founded to commemorate important contributions toward our knowledge of heat and light, has just been granted to Dr. John William Draper, of New York. This is a distinguished tribute to the scientific labors of our eminent physicist and chemist, and the Academy has honored itself in the award. Yet, those who know how early and eminent were Dr. Draper's original contributions to the chemistry of light, will be tempted to ask why this distinction was not accorded by the Academy to Dr. Draper a generation ago. As reminiscences of Count Rumford are being revived just now, it will be interesting to glance at the history of his medals, which have attained such celebrity in the scientific world.

Deeply impressed with the importance of extending the knowledge of heat and light, to which he had devoted himself with great assiduity and success, Count Rumford, in 1796, presented to the Royal Society £1,000, the interest of which was to be spent in striking two medals both in the same die, one of gold and one of silver, worth the interest of the donation for two years, and to be given biennially for the most important discovery or improvement relating to heat and light that should have been made during the preceding two years in any part of Europe. The trust was accepted and the medals designed. The first award was to Rumford himself in 1802. In 1804 John Leslie received the Rumford medals. The honor then passed, in 1806, to Murdock; in 1810 to Malus; in 1814 to Dr. Wells; in 1816 to Humphry Davy; in 1818 to David Brewster; in 1824 to Fresnel; in 1834 to Melloni; in 1838 to J. D. Forbes; in 1840 to Biot; in 1842 to Fox-Talbot; in 1846 to Faraday; in 1848 to Regnault; in 1850 to Arago; in 1852 to Stokes; in 1854 to Arnott; in 1856 to Pasteur; in 1858 to Jamin; in 1860 to Clerk-Maxwell; in 1862 to Kirchhoff; in 1864 to Tyndall; in 1866 to Fizeau; in 1868 to Balfour Stewart.

At the same time Count Rumford made a corresponding donation to the

American Academy of Arts and Sciences, instituted in 1780. Five thousand dollars were presented, the accruing interest of which was to be invested in medals, and granted biennially by the academy for the most important discoveries in relation to heat or light made within the preceding two years. It was also provided that, if this term passed without any discovery or improvement being made that should be deemed worthy of the award, the accruing interest was to be added to the principal, and the augmented income thus arising was to be added to the medals when the next award was made. But the arrangement seemed to be a futile one, as there were none in America who troubled themselves to extend the knowledge of heat and light; or, at all events, there were no such extensions as in the opinion of the Academy were entitled to win the prizes. Years passed, and the money accumulated until the Academy became embarrassed by the question what to do with it. And so they got a law passed by the Legislature empowering them to depart from the strict letter of the endowment, and use the funds with more freedom in the interest of advancing knowledge. In 1839 the Academy gave from the interest of the Rumford fund the sum of $600 to Dr. Hare, of Philadelphia, in consideration of his invention of the compound blowpipe, and his improvement in galvanic apparatus. The Rumford medal was granted by the Academy, in 1862, to John B. Ericssen for his caloric-engine; in 1865 to Daniel Treadwell, for improvements in the management of heat; in 1867 to Alvan Clark, for improvement in the lens of the refracting telescope; and in 1870 to George H. Corliss, for improvements in the steam-engine. When the gift was made to Dr. Hare, the fund amounted to $27,000; and it has now grown to $42,000.

The biographer of Rumford makes the following significant observation: "It is remarkable that the count, after having liberally provided funds for medals in the award of two learned bodies, should a few years afterward, when drawing his plan and publishing his proposals for his own Royal Institution, have introduced into them an express prohibition of all premiums and rewards."

LITERARY NOTICES.

ON FERMENTATION. By P. SCHÜTZENBERGER. With Twenty-eight Illustrations. Pp. 306. Price, $1.50. D. Appleton & Co. No. XX. International Scientific Series.

IN the logic of science, the misleading influence of words is a matter of ever-increasing importance. Words remain, but the ideas they represent are altered, expanded, revolutionized. The old and narrow meanings live on in common speech, and the changed and enlarged significations are current among men of science, so that when the terms are employed between these classes they have so totally different a signification that intelligent and critical interchange of ideas between them is hardly possible. The term applied to the present work is a case in point. The word "fermentation" is derived from *fervere*, to boil, and applies to the agitation or effervescence of saccharine liquids when placed in contact with ferments—a phenomenon that was probably familiarly known long before the earliest traces of history. To the mass of people, the word "fermentation" suggests bread-making and brewing, with the production of spirituous and souring products. To the man of science and as treated in the present volume, fermentation has become one of the great gateways to biology. The subject has ever been, and must continue to be, of great practical moment in its domestic and manufacturing relations; and every step in its scientific elucidation is therefore a contribution to the theory and progress of the arts. The knowledge of it has now become so clear and extended, that it was necessary it should be brought together in a special treatise for reference for all who are interested in practical problems of organic chemistry. But while the present book fulfills this condition, it also aims at the

higher object of bringing the principles of the subject into relation with philosophical biology. The scientific significance of fermentation lies in the fact that it brings before us the action and effects of the lowest and most elemental forms of living organisms; it deals with the behavior and influence in numerous relations of elementary organisms reduced to a single cell; but these cells are the units of all organic life, a plant or an animal of a higher order being only the union under special laws of different kinds of cells, each of which acts in a certain determinable manner. While the higher organisms baffle analysis from the infinite complexity and diversity of their minute or histological elements, the key to their study is offered in these lower structures, for "the more simple an organism is, the fewer special kinds of cells it contains, the simpler are the chemical reactions which take place in it, and the more easily are they separated from each other and isolated by experiment;" and from this point of view the history of fermentation becomes nothing less than that of the chemical phenomena of life. The thorough study of ferments, therefore, becomes an indispensable scientific prerequisite to the knowledge of the higher organisms.

The investigation of the influence of different ferment-cells in initiating different lines of chemical change brings us into closer quarters with the relations of chemical and so-called vital forces. As the different radiant forces, thermal, luminous, and chemical, produce their profoundly diverse effects simply by variations of wave-length, so the different kind of cells are supposed to initiate different chemical changes by differences in the vibratory rhythm which starts them. In relation to this point our author remarks:

"The transformation of sugar into alcohol and carbon dioxide and the conversion of the same body into lactic acid are chemical phenomena which we cannot yet reproduce by the intervention of heat alone, nor by the additional agency of light or of electricity. The force capable of attacking, in a certain determinate direction, the complex edifice which we call sugar, an edifice composed of atoms of carbon, hydrogen, and oxygen, grouped according to a determinate law—this force, which is manifested only in the living cell of the ferment, is a force as material as all those which we are accustomed to utilize. Its principal peculiarity is, that it is only found in the living organisms, to which it gives their peculiar character. We ought not to allow ourselves to be stopped by this rampart, over which no one has hitherto been able to pass; we ought not to say to the chemist, 'You shall go no farther, for beyond this is the domain of life, where you have no control.' The history of science shows us the weakness of these so-called impassable barriers. No one can any longer admit that vital force has power over matter, to change, counterbalance, or annul, the natural play of chemical affinities. That which we have agreed to call chemical affinity is not an absolute force; this affinity is modified in numberless ways, according as the circumstances vary by which bodies are surrounded. Thus, the apparent differences between the reactions of the laboratory and those of the organism ought to be sought for, more particularly among the *special conditions*, which the latter alone has been able hitherto to bring together. In other words, there is really no chemical vital force. If living cells produce reactions which seem peculiar to themselves, it is because they realize conditions of molecular mechanism which we have not hitherto succeeded in tracing, but which we shall, *without doubt*, be able to discover at some future time. Science can gain nothing by being limited in the possibility of the aims which she proposes to herself, or the end which she seeks."

MEMOIR OF SIR BENJAMIN THOMPSON (Count Rumford), with Notices of his Daughter. By GEORGE E. ELLIS. Published, in connection with an edition of Rumford's Complete Works, by the American Academy of Arts and Sciences. Boston. Pp. 680.

Rumford's Complete Works, vol. I., pp. 493. Vol. II., pp. 570. Vol. III., pp. 504. Vol. IV., pp. 842. Price of the set, including the "Life," $25.00. Boston: Estes & Lauriat.

WE elsewhere publish a brief notice of the life of Count Rumford — so brief as hardly to give a just idea of the interest that attaches to the romantic and remarkable story of his career. But few biographies are richer in varied incident, or fuller of instruction, than this of Rumford; and its literary execution, by Mr. Ellis, is well worthy of the subject. The four volumes of his works comprise not only all the Count's essays, formerly published in English, but also valuable papers written by him in French and German which have been first translated for this edition. The collection has been supervised by the Rumford Committee of the American Academy of Sciences, who have grouped together in the several volumes, as far as was practicable, the papers on allied subjects: thus the sci-

entific papers will be found chiefly in the first two volumes; descriptions of improved methods of warming and cooking occupy the third; and the greater part of the last is devoted to philanthropic essays; but this also contains the scientific papers on light. The volumes are splendidly illustrated and elegantly printed. The American Academy of Sciences could have given no worthier tribute to the fame of this man than to furnish the world with so excellent an edition of his writings.

LIFE-HISTORIES OF THE BIRDS OF EASTERN PENNSYLVANIA. By THOMAS GENTRY. In Two Volumes. Vol. I. Pp. 400. Philadelphia: The author.

THIS work is intended to present more fully than has been done before the habits, food, migrations, and other characteristics of the birds of Eastern Pennsylvania.

Especial attention is given to the building of nests; showing wherein they vary, and the causes for such variations.

The labor of nidification; the periods of incubation, and the part which the male takes in it; the age when the young quit their nests; the character of the sexes before and after incubation; and the food, as insects, seeds, and berries, on which the birds, old and young, depend, are carefully considered by the patient and indefatigable author.

Very much of value is thus added to our knowledge of bird-life, and what is specially important to our knowledge of the instincts and mental constitution and emotions of birds.

We look for good results from the labors of Mr. Gentry. The system of classification he adopts is the same as that of Dr. Elliott Coues in his "Key to North American Birds."

REPORT OF THE TRUSTEES OF THE HARVARD MUSEUM OF COMPARATIVE ZOÖLOGY.

GIVES an account of all changes and additions in the various sections of the Museum during 1875. From the report on instruction in zoölogy, it appears that during the year 1874–'75 there were eighteen students attending the lectures of Prof. McCrady. A detailed statement is made of the condition of the Agassiz Memorial Fund.

THE PHYSIOLOGY OF THE CIRCULATION IN PLANTS, IN THE LOWER ANIMALS, AND IN MAN. By J. BELL PETTIGREW, M. D., F. R. S. London and New York: Macmillan. Pp. 329. Price, $4.

IN this work we have what the *Lancet* justly calls "the first serious attempt at a great generalization on an avowedly difficult subject." The author has undertaken no less a task than to show that the circulation, as it takes place in plants, animals, and man, is essentially the same in kind; differing mainly in the degree of complexity attained by the organs which carry it on, and of the resulting movements of the circulating fluids.

The book opens with a brief history of the growth of the subject, from the fanciful notions held centuries ago by the Chinese that "the circulation of the vital heat and radical humors commenced at three o'clock in the morning, reached the lungs in the course of the day, and terminated in the liver at the end of twenty-four hours," up to the exact scientific demonstrations of Harvey and Malpighi. "The term 'circulation,' in the present day," says the author, "is employed in a double sense. In its wider signification it embraces the course of the nutritious juices through plants and the lower order of animals; in its more limited signification, and as applied to man and the higher orders of animated beings, it indicates the course of the blood from the heart to the capillaries, and from these back again to the heart. The word 'circulation' literally means a *flowing round*, a going and returning; and it is well to bear the original meaning in mind, as we shall find that a single circle aptly represents the circulation in most of the lower animals, a circle with one or more accessory loops, representing the circulation in the higher ones."

The circulation in plants is first described, the ascent, descent, and lateral distribution of the sap, and the forces which maintain the flow, being each fully treated. Many curious resemblances between the circulation in plants and that in animals are pointed out in this section of the work. On this point the author says: "I now proceed to a consideration of the circulation as it exists in animals; and an attentive examination of the subject not only induces me to believe that there is a striking analogy

between the circulation in animals and plants, but that in animals devoid of pulsatile vessels and hearts it is in some senses identical, and traceable to the operation of the same forces."

The subject of the circulation in animals occupies the bulk of the book, that of the invertebrates, as being in some sense intermediate between plants and the higher animals, being treated first. In a number of the lowest of these no trace of a circulation has yet been detected, the nutritious fluids in such cases being supposed to pass from the alimentary canal by interstitial transudation throughout the entire body, as the sap passes into the substance of cellular plants. A step in advance is observed where, as in the polypi, medusæ, etc., the alimentary canal is of large size and ramifies in every part of the body, serving at the same time as a circulatory and alimentary apparatus. The next advance is the appearance of distinct vessels, *minus* contractile power, as in plants. Vessels possessing contractile power, but without any distinct contractile organ, are next found; and afterward the heart appears, increasing in complexity of structure along with the related organs, until its highest development is reached in the mammalia.

On the subject of the forces which give rise to the circulation in the higher animals, the author, while admitting that a large share of the work is done by the heart, argues at length in favor of the view that this organ alone is not equal to the task; and that other agencies, such as osmosis, capillary attraction, absorption, chemical affinity, etc., aid materially in the process.

To the physiological student the book is exceedingly interesting, not only for the novel views which it contains, but for the admirable way in which the author has presented the leading facts of his subject, as drawn from the whole range of living Nature. The print is good, and the illustrations, of which there are one hundred and fifty, are also well done.

LECTURES ON SOME RECENT ADVANCES IN PHYSICAL SCIENCE. By P. G. TAIT, M. A. Pp. 337. Macmillan & Co. Price, $2.50.

THE disputes that have arisen in various quarters regarding the honor due to different investigators for working out the modern doctrines of "Energy" have been participated in by Prof. Tait, of Edinburgh, and this volume is probably due to his interest in the controversy. He was invited by a number of his friends to give a course of lectures on the chief advances made in natural philosophy since their student-days, and the author remarks that "the only special requests made to me were, that I should treat fully the modern history of energy, and that I should publish the lectures verbatim." The strictly historic part, however, is by no means the main, or the most important, feature of the work. It furnishes its method, but the book is valuable chiefly as explaining and expounding the modern doctrines of energy in a manner at once popular and thorough. No adequate exposition of these views has yet gained entrance into our text-books of physics; and a work was much needed, by a competent man, which would present the whole question in its latest aspects. The volume of Prof. Tait, though not without its defects, may be commended as meeting this want in a tolerably satisfactory manner.

THROUGH AND THROUGH THE TROPICS. By FRANK VINCENT, Jr. New York: Harper & Brothers. Pp. 304.

THIRTY thousand miles of travel affords large opportunity for observations, and to give an account of them in a book of three hundred pages seems a hopeless task. Mr. Vincent, however, has made the attempt in this racy book, and has succeeded fairly in presenting a series of descriptions of some of the more important places visited by him, and the reader follows him with interest to the close. His chapters on the Sandwich Islands, and on the journey to High Asia, to the sacred city of the Hindoos, and to the famous Taj Mahal, are especially full of interest.

THE EARLY LITERATURE OF CHEMISTRY. VI. By H. C. BOLTON.

THIS sixth part of Dr. Bolton's "Notes on the Early Literature of Chemistry" treats of the ancient papyrus-book on medicine discovered by Ebers at Thebes, Egypt, two or three years ago. Dr. Bolton gives the table of contents of the book with some selected passages translated out of the hieratic original.

A TREATISE ON THE DISEASES OF THE NERVOUS SYSTEM. By WILLIAM A. HAMMOND, M. D. New York: D. Appleton & Co. Pp. 883, with 109 Illustrations. Price, $6.

THE standing of this work may be inferred from the fact that it has gone to the sixth edition, and, having been out of print a year, reappears rewritten, enlarged, and much improved. Dr. Hammond has made the subject of this work a specialty, and his extensive medical practice in the department of nervous diseases can hardly fail to give much practical value to his treatise upon the subject. The work is written for medical students and the profession, but other people can collect a great deal of information from it, curious and valuable, in regard to nervous actions, conditions, and disorders.

In his preface Dr. Hammond says: "One feature I may, however, with justice claim for this work, and that is, that it rests to a great extent on my own observation and experience, and is, therefore, no mere compilation. The reader will readily perceive that I have views of my own on every disease considered, and that I have not hesitated to express them." Obviously, the great obscurity and unsettledness of our knowledge, both of the physiology and pathology of the nervous system, offer a strong temptation to confident minds to form and promulgate positive opinions concerning them, but the same causes should enforce caution upon the student in their acceptance.

PAINTERS' MAGAZINE. Monthly, pp. 40. A. G. Sullivan, Editor and Publisher.

THE eighth number of the second annual volume has just been published, and presents to its readers an excellent and varied table of contents, besides some useful illustrations for the practical painter, artist, etc. The contributions are from some of the best writers of the day upon the various branches of painting. This magazine must be useful not only to the painter, but also to the architect and builder. That a better idea may be had, we give the headings of leading articles, viz.: House-Painting; Interior or Mural Decoration; Pigment and Color; Hints on Drawing; Answers to Correspondents; Railway-Car Painting, etc. Price, $1.50 per annum.

MAGNETISM AND ELECTRICITY. By F. GUTHRIE. New York: Putnams. Price, $1.50.

IN this little volume, Prof. Guthrie, of the Royal School of Mines, London, presents to the general student of magnetism and electricity a very full compendium of that science. In directness of statement and clearness of expression this treatise is deserving of very high praise, and these qualities it doubtless owes to the circumstance that it is based upon the notes of the lectures delivered by the author for many years to mining students and science-teachers. The work is illustrated with over 300 woodcuts.

NOTES ON BUILDING CONSTRUCTION. For sale by Lippincott, Philadelphia.

THIS is the first of a series of three volumes, intended to assist pupils who are preparing for the examinations in building construction held annually under the direction of the Science and Art Department of the British Government. This first part treats of the points laid down as necessary for the examination in the elementary course. The subjects discussed are: Walling and arches; brickwork; masonry; carpentry; floors; partitions; timber roofs; iron roofs; slating; plumbing; cast-iron girders; joinery.

LEGAL CHEMISTRY. By A. NAQUET. Pp. 178. Price, $2. New York: Van Nostrand.

THE title of this work sufficiently indicates its purport, namely, the solution of chemical problems arising in the administration of justice. As a matter of course, the subject of the detection of poisons receives the most attention; but the author also describes the processes to be adopted for examining sundry alimentary and pharmaceutical substances, for examining written documents, blood-stains, etc. The translator of the work, Dr. J. P. Battershall, appends a list of books and memoirs on the subject of toxicology and the allied branches.

PRINCIPAL CHARACTERS OF THE DINOCERATA. By Prof. O. C. MARSH.

THIS is a reprint from the *American Journal of Science and Art*. Besides the letter-press, the paper contains six lithographic plates giving views of the skull, dentition, jaw, feet, etc., of Dinocerata.

PUBLICATIONS RECEIVED.

Structure and Relation of Dinichthys. By J. S. Newberry. Pp. 64. With Plates. Columbus, Ohio: Nevins & Myers.

Chemistry, Practical and Analytical. Parts 1, 2, 3, 4, 5. Philadelphia: Lippincott & Co.

Report on Vienna Bread. By E. N. Horsford. Pp. 130. Washington: Government Printing-Office.

Worcester Lyceum and Natural History Association. By N. Payne. Pp. 13.

Land and Fresh-Water Mollusca found in the vicinity of Cincinnati. Pp. 5.

Man: Palæolithic, Neolithic, etc., not inconsistent with Scripture. By Nemo. Dublin: Hodges, Foster & Co. Pp. 137. Price, five shillings.

Bulletin of the United States Geological and Geographical Survey of the Territories. Vol. II., Nos. 1 and 2. Washington: Government Printing-Office. Pp. 90 and 100.

Bulletin of the Bussey Institution. Part 5. Pp. 95

Roads, Streets, and Pavements. By Brevet Major-General Gillmore. Pp. 258. New York: Van Nostrand. Price, $2.

American Catholic Quarterly Review. Vol. I., No. 2. Pp. 190. Philadelphia: Hardy & Mahony. Price, $5 per annum.

Tansactions of the Kansas Academy of Science. Vol. IV., pp. 64. Topeka: G. W. Martin, Printer.

Geological Survey of Ohio. Paleontology, Vol. II., pp. 432, with numerous Plates; Geology, Vol. II., pp. 700, with Maps. Columbus: Nevins & Myers, State Printers.

Physics and Hydraulics of the Mississippi River. By J. B. Eads, C. E. Pp. 33. New Orleans: *Picayune* Print.

The Drift of Devon and Cornwall. By T. Belt, F. G. S. Pp. 11.

Urinary Calculus. By W. F. Westmoreland, M. D. Pp. 11. Atlanta, Georgia: Dunlop, Wynne & Co.

The "One-Rail" Railroad. By C. J. Quetil. New York: Cheap Transportation Association.

List of Skeletons and Crania in the Army Medical Museum, Washington. Pp. 52.

The Opium-Habit. By S. E. Chaillé, M. D. Pp. 9. From the *New Orleans Medical and Surgical Journal*. Also, Climatotherapy of Consumption. Same author. Pp. 16.

Michigan State Board of Health Report, 1875. Pp. 170.

Transcendentalism. By Theodore Parker. Boston: Free Religious Association. Pp. 39. Price, 10 cents.

Mechanical Construction of Water, By Captain J. E. Cole. Pp. 27. New York: E. O'Keefe, Printer.

Hospitals for the Sick and Insane. Pp. 54. Albany: Weed, Parsons & Co.

Deed of Trust of James Lick. Pp. 24.

New Orleans Price Current, 1876. Pp. 89.

MISCELLANY.

A Moth that bores for its Food.—The order of *Lepidoptera*, which includes moths and butterflies, is almost universally characterized as possessing a flexible trunk, by means of which the insects suck up the nectar of flowers. Indeed, the possession of a flexible trunk is commonly regarded as one of the distinguishing characteristics of this order. A few years ago, however, a French botanist, M. Thozet, then residing in Australia, discovered a moth (*Ophideres fullonica*) which possessed a trunk so rigid as to be able to pierce the rinds of oranges and suck their juice. Another Australian observer having since called attention to the depredations of this moth, M. J. Künckel was led to examine the trunks of *Ophideres* which had been sent to him from Australia by M. Thozet. This trunk he declares to be a perfect instrument, and says that it would be an excellent model for the making of new tools to be employed in boring holes in various materials. It resembles the barbed lance, the gimlet, and the rasp, and hence can pierce, bore, and tear, at the same time allowing liquids to pass without impediment by the internal canal. The two applied maxillæ constituting the organ terminate in a sharp triangu-

lar point, furnished with two barbs; then they become enlarged, and present on the lower surface three portions of the thread of a screw, while their sides and their upper surface are covered with short, strong spines, projecting from the centre of a depression with hard and abrupt margins. The purpose of these spines is to tear the cells of the orange-pulp, as the rasp serves to open the cells of the beet-root, in order to extract sugar. The upper region of the trunk is covered below and on the sides with fine, close-set striæ, arranged in half-screws, which give it the properties of a file; the striæ are interrupted here and there by small spines of soft consistence, which serve for the perception of tactile sensations. The orifice of the canal is situated in the lower surface, below the first screw-third. All this will be seen better from the annexed figures:

TRUNK OF *Ophideres fullonica*.—*A*, in Profile; *B*, from below; *C*, from above; *t*, Interior Canal; *o*, Orifice of the Canal.

On investigation, M. Künckel has found that *all* the species of the genus *Ophideres* possess a similar terebrant trunk. This circumstance establishes a closer relationship between the *Lepidoptera*, the *Hemiptera*, and certain *Diptera* in which the maxillæ are adapted to pierce tissues.

As we learn from Prof. A. R. Grote, the group of *Noctuidæ* to which *Ophideres* belongs, called by Borkhausen *Fasciatæ*, is represented by only a few forms in Europe, but it is largely developed in the tropics of both hemispheres. The peculiar structure of the maxillæ observed in *Ophideres* has not been found in any of the North American genera of the group. In the genus *Catocala*, which is largely represented in North America, the spiral tongue or trunk is simply furnished with lateral papillæ, appearing like serratures, toward the extremity of the trunk.

Cunning of the Adder.—A correspondent of the Milwaukee *Sentinel* confirms Mr. Lewis's observations on the cunning of the adder (in the February number of the MONTHLY). This correspondent states that, over thirty years ago, in Leeds, Greene County, New York, his attention was one day attracted by the plaintive cry of a cat. Looking into a garden, an adder was seen near the cat. The cat seemed to be completely paralyzed by fear of the adder; she kept up the plaintive cry, as if in great distress, but did not take her eye off the serpent, or make any attempt to attack or escape. Soon the snake saw that human eyes were observing him, and he commenced to crawl slowly away. "I then," continues the writer of the narrative, "concluded to release the cat from its trouble. I took a garden-rake and put it on the snake's back, and held it without hurting it. As soon as I had the snake fast in this position, it raised its head, flattened it out, and blew, making a hissing noise, and something resembling breath or steam came from its mouth. When that was exhausted I removed the rake, and the adder turned over on its back, lying as if dead. With the rake I turned it over on its belly again, but it immediately turned on its back. This was repeated several times. At last it was taken out of the garden, laid in the road, and we all retired to watch its movements. It commenced to raise and turn its head slowly (looking about the while), until entirely on its belly, and started at full speed for a little pool of water in the road, from which it was raked out and dispatched."

Measuring Distances by Sound.—The Prussian correspondent of the London *Times* makes mention of an instrument devised by Major Le Boulanger, of the Belgian Artillery, which, with great accuracy, indicates the distance between two armies from the report of their guns. The mo-

ment the enemy fires a shot, the action of the report upon the "telemeter" marks the distance to a fraction. The instrument is entirely self-acting, easily kept in order, and requires no particular experience or intricate calculations to use it aright. The experiments to which it has been subjected in Prussia and in some other countries are stated to have been completely successful as regards cannon. Experiments in the rifle-grounds are still going on. Even should the invention be confined to artillery, its effect must be tremendous, considering the present deadly efficiency of fire-arms. One of its principal advantages, it is supposed, will be to enable gunners in a coast-battery to determine the position of a hostile ship—a calculation hitherto fraught with special difficulty.

Sir John Lubbock on the Habits of Ants.—Sir John Lubbock still continues his observations of ants, and at a recent meeting of the Linnean Society of London read a paper in which he treated—1. Of the power of intercommunication among ants; 2. Their organs of sense; 3. Their affection or regard for one another. The results are chiefly negative, contradicting many generally-received opinions. To test the ants' power of communicating information to one another, the author had a glass box for the "nest," so that he could watch what was done inside. This was placed on a pole. On the other side of the pole was a board intended as a promenade for the ants. Near to this were three pieces of glass, connected with the board by strips of paper. On one of the pieces of glass was placed a collection of food, and on the other two there was nothing. Two ants were taken and marked with spots of color, as in former observations, so that they should be readily recognized. These were both taken, one after the other, to the store of food, and were guided and taught their way to the nest. They soon learned their way to and from the nest to the food-supply, coming out of the door along the outside to the pole, around that, across the board, along the paper bridge, and so to the glass that supported the food, and so back again to the nest. Sir John Lubbock's object was to watch whether the other ants in the nest would find out the food, and, if so, to test as far as possible whether they found it from information given, or whether they tracked the scent. He devoted certain periods to watching the movements of the ants, counting the number of journeys made by his marked ants, and also recording how many untaught strangers made their way from the board along the right bridge to the food. At his first period of observation he found that, while his marked ants made forty journeys with food, nineteen strangers also came on to the bridges. Of these, two only turned to the food, eight turned to the wrong bridge, and the rest went straight on. Modifications in the arrangements of the bridges were made in different ways, while the rest of the construction was left unaltered. The observations made on different days and during periods of different duration all showed the same result.

In referring to the organs of sense, Sir John had endeavored to ascertain whether the antennæ are organs of hearing or of smell. He had tried them with all sorts of noises he could contrive, and found no results. If ants have hearing, they must be sensible to those vibrations of the air which do not affect the human ear. But he had also tried the antennæ with smells, and he found that if he put a fine camel's-hair pencil with a scent on it near one of them it shrank away, and then, if applied to the other, that also turned away. The use of the antennæ, however, still needs investigation, and Sir John hopes soon to make further observations. As regards their affection for one another, he does not doubt that an ant that dies laden with food will be cared for by its companions; but he brought forward a number of instances in which he had put ants that had suffered immersion in water for periods of from an hour to ten hours in the way of ants that were passing by, and he found almost invariably that they took no notice of their unfortunate brethren. Indeed, the exceptions in which any attention was paid were so few that Sir John said he was disposed to regard these as ants with individual feelings, which were by no means those common to the community. It is understood that the results of Sir John Lubbock's long-continued researches into the habits of bees

and ants will be given to the public before long in a volume of the "International Scientific Series."

Sea-Soundings without a Line.—Dr. Siemens exhibited, at a recent meeting of the London Royal Society, an instrument devised by himself for ascertaining the depth of the sea. In explaining the principle of this instrument, Mr. Siemens observed that the total gravitation of the earth, as measured on its normal surface, is composed of the separate attractions of its parts, and that the attractive influence of each equal volume varies directly as its density and inversely as the square of its distance from the point of measurement. The density of sea-water being about 1.026, and that of the solid constituents composing the earth's crust about 2.763, it follows that an intervening depth of sea-water must exercise a sensible influence upon total gravitation if measured on the surface of the sea. His instrument, which he calls a bathometer, is described in the London *Times* as consisting "essentially of a vertical column of mercury, contained in a steel tube having cup-like extensions at both extremities, so as to increase the terminal area of the mercury. The lower cup is closed by means of a corrugated diaphragm of thin steel plate, and the weight of the column of mercury is balanced in the centre of the diaphragm by the elastic force derived from two carefully-tempered spiral steel springs of the same length as the mercury-column. One of the peculiarities of this mechanical arrangement is, that it is parathermal, the diminishing elastic force of the springs with rise of temperature being compensated by a similar decrease of potential of the mercury-column, which decrease depends upon the proportions given to the areas of the steel tube and its cup-like extensions."

The instrument is suspended in such a manner as to retain the vertical position, notwithstanding the motion of the ship, and the vertical oscillations of the mercury are almost entirely prevented by a local contraction of the mercury-column to a very small orifice. The reading of the instrument is effected by means of electrical contact, which is established between the end of a micrometer-screw and the centre of the elastic diaphragm. The pitch of the screw and the divisions in the rim are so proportioned that each division represents the diminution of gravity due to one fathom of depth. Actual experiment has shown the apparatus to be very reliable.

Formation of Mountain-Chains.—This subject is considered by Prof. Joseph Le Conte in the April number of the *American Journal of Science*, in which interesting facts are presented, the results of observations made by the author in the Coast Range of California. He finds that the actual length of the folded strata is about two and a half to three times the horizontal distance through the mountains. It thus appears that from fifteen to eighteen miles of strata, that is, of original sea-bottom, has been crushed or mashed into six miles, with "corresponding up-swelling of the whole mass."

This diminution of distance, according to the theory of Prof. Le Conte, has not arisen from *folding* of the strata, but by *mashing* of them by horizontal pressure.

From the flattened and elongated form of little nodules of clay found in some of the strata, he concludes that their elongation vertically exactly correlates their shortening horizontally, and that the one is to the other as two and a half or three is to one. It thus appears that in the compression of the beds their constituent particles underwent a change of form corresponding with the conditions of the pressure.

These clay pellets or nodules are supposed to have been formed on the bottom of gently-flowing streams, are a part of the original sedimentary beds, and are the same in character as those which form greenish spots in slate, as described by Prof. Tyndall.

It will be seen that, in accounting for the elevation of mountain-chains, Prof. Le Conte differs from Prof. Dana in this: that while they agree that mountain-chains are formed by yielding of the earth's crust, Prof. Dana attaches importance chiefly to the bending and plication of it, Prof. Le Conte to the crushing of it. He says, "I am satisfied that Prof. Dana greatly underestimates the amount of elevation by simple mashing as compared with folding."

Brain-Weight and Mental Power.—Great weight of brain is commonly regarded as evidence of great cerebral power. That this conclusion, however, is erroneous, is shown by Dr. Robert Lawson, who, in the *Lancet*, compares the brain-weights of some of the great men of modern times with the brain-weights of lunatics who died in the West Riding Asylum. He gives the following instructive table:

	Ounces.		Ounces.
Brain-weight of Dr. Chalmers....	53	Lunatic	58
" Daniel Webster..	53.5	"	58
" Sir J. Y. Simpson	54	"	58.5
" Goodsir	57.5	"	59.5
" Abercrombie	63	"	60.5
" Cuvier	64	"	61

It will be observed that only Abercrombie and Cuvier surpass in weight of brain the inmates of the asylum. One of these lunatics, he whose brain weighed 61 ounces, was seventy-one years of age when he died; when he was forty-five, his brain probably weighed not less than 64 ounces, thus equaling in weight the brain of the great Cuvier, and exceeding that of Daniel Webster by 20 per cent. From all this it follows that great weight of brain is not in itself a conclusive evidence of great intellect.

From this comparison of brain-weights, Dr. Lawson passes to the consideration of the relations between genius and insanity. "Every day," he says, "the observation of the poet, that great wit is nearly allied to madness, gains a wider and more practical acceptance. So much is this the case that Dr. Wilks ventures to make the statement that it is probably the insane element which imparts what we call genius to the human race, the true celestial fire. And though it is fearful to think of the propagation of a race tainted with insanity, yet it does not follow that an infusion of the insane blood may not be desirable. Dr. Maudsley holds the same opinion."

Preservation of Zoölogical Specimens.—Last summer, Profs. Verrill and Rice, of Yale College, made a number of experiments to ascertain the effects of various chemical preparations upon marine invertebrates, the objects being to improve existing methods of preserving specimens and to ascertain the best means of killing in an expanded state species which ordinarily contract very much when put directly into alcohol. The results are given in the *American Journal of Science*, by Prof. Verrill, who says that several very fine preparations of *Actiniæ* in a state of nearly perfect expansion were made by slowly adding a concentrated solution of picric acid to a small quantity of sea-water in which they had been allowed to expand. When fairly dead, they were transferred to a pure saturated solution of the acid, and allowed to remain from one to three hours. They were then placed in alcohol for permanent preservation. The alcohol should be renewed after a day or two, and this should be repeated until all the water has been absorbed from the specimen. Hydroids and most kinds of jelly-fishes can be easily preserved in the same way. Even delicate *Ctenophoræ* can be thus preserved so as to make fair specimens. The experiments were made with the view of finding some poison that will kill mollusks, especially gasteropods, in a fully-extended state, but the results were negative; at least no method was discovered that is more generally successful than that of allowing them to suffocate in stale sea-water, through excess of carbonic acid and deficiency of oxygen.

Improvement of the Steam-Engine.—In giving testimony before the Government Commissioners on the Advancement of Science in Great Britain, Mr. Anderson, superintendent of machinery at Woolwich, spoke of Joule's experiments on the conservation of energy as of immense value and as being an example of what government should do for the common good. Joule had made engineers thoroughly dissatisfied with their present knowledge as to what they can do with steam. "I believe," he continued, "that what Joule did will do more for this country than even what James Watt did. The part that James Watt took was very great, and the world gives him full credit for it; but the world is scarcely willing to give credit to Joule. Engineers know that the best steam-engine is not doing one-sixth of the work which it ought to do and can do. That is a sad state of matters to be in when we know that we are so far wrong, but yet no one will go to the trouble of going to the end of the question so as to improve the steam-engine as it might be done."

Underground Forests in the Thames Valley.—An interesting geological discovery, as we learn from *Nature*, was recently made during excavations for a new tidal basin at the Surrey Commercial Docks, London. On penetrating some six feet below the surface, the workmen everywhere came across a subterranean forest-bed, consisting of peat with trunks of trees, for the most part still standing erect. All are of species still inhabiting Britain; the oak, alder, and willow, are apparently most abundant. The trees are not mineralized, but retain their vegetable character, except that they are thoroughly saturated with water. In the peat are found bones of the great fossil ox. Fresh-water shells are also found. No doubt is entertained that the bed thus exposed is a continuation of the old buried forest which has been brought to light at various other localities on both sides of the Thames. In each case the forest-bed is found buried beneath the marsh-clay, showing that the land has sunk below the tidal level since the forest flourished.

The Medication of Infants.—From experiments made by Dr. Lewald it appears that sundry medicines are most advantageously introduced into the system of an infant through the mother's milk. Thus of iron a larger quantity can be administered to the infant in this way than by any other means. Bismuth, however, is eliminated in the milk only in very small quantity. Iodine does not appear in the milk until ninety-six hours after taking it; iodide of potassium appears four hours after ingestion, and continues to be eliminated for eleven days. Arsenic appears in the milk at the end of seventeen hours, and continues for at least forty hours. Oxide of zinc, though one of the most insoluble preparations, is eliminated by the milk; it disappears sooner than iron. The elimination of antimony is an undeniable fact, and it is well to bear this in mind during the period of nursing; the same holds true in regard to mercurial preparations. That alcohol and narcotics are eliminated by the milk has not been demonstrated. Sulphate of quinine is eliminated very easily, and a child suffering from intermittent fever was cured by administering quinine to the nurse.

NOTES.

The printing-press at which Benjamin Franklin worked in London will be exhibited at Philadelphia. This press was at one time the property of Harrild & Sons, of London, but in 1841 they allowed it to be forwarded to Philadelphia. By way of acknowledgment, a sum of money was to be handed over to the Printers' Pension Corporation, for the purpose of founding a pension for an aged printer. This has never been done, and hence Franklin's press by right belongs to Messrs. Harrild, and should appear at the Centennial Exhibition as an English and not an American exhibit.

In the "Annual of Natural Science," of Würtemberg, Otto Hahn has an elaborate review of the *Eozoön Canadense* question. This article, which is very long, is published in the *Annals and Magazine of Natural History*, for April. The author, after an examination of the geological, the mineralogical, and the zoölogical facts, pronounces the so-called eozoon structures to be purely mineral in their origin.

In replying to Tyndall, Dr. Bastian cites a number of investigators as supporting his views on biogenesis. Among the authorities thus quoted are E. Ray Lankester and Dr. Pode; but the former of these two gentlemen now writes to *Nature*, saying that their (i. e., Lankester's and Pode's) results "conclusively and categorically contradict the particular assertions contained in Dr. Bastian's book, 'The Beginnings of Life,' into the truth of which they set themselves to inquire."

Specimens of paper and cardboard made from peat were recently presented to the Berlin Polytechnic Association by Herr Veyt-Meyer. The paper and cardboard were very firm, and the latter was so thick that it might be planed and polished. Paper made of peat alone is like that made from wood or straw; but only fifteen per cent. of rags is needed to give it consistence. A large factory for the manufacture of peat paper is to be established in Prussia.

In order to act intelligently against the cotton-worm, Southern planters are advised by Prof. A. R. Grote to act in concert. He further recommends that, whatever agent is employed to destroy the worm, be used against the first brood that appears in the locality, so as to prevent its spreading farther. It is highly desirable that the life-history and habits of such insect-pests should be thoroughly studied, with a view to their extermination.

Prof. Benjamin Silliman, of Yale College, has patented a process for giving reso-

nance to sundry alloys, such as britannia metal, pewter, etc., which commonly give only a dull sound when struck. According to the *Engineering and Mining Journal*, the process consists in submitting articles made of these alloys to the action of a certain degree of temperature, just below their melting-point, for a short time, in a bath of oil or paraffine. The theory of the process appears to turn upon a rearrangement, perhaps a crystallization, of the molecules.

THE Phylloxera Commission, appointed by the Paris Academy of Science, to award the Government prize of 300,000 francs for the discovery of an effectual means of destroying the *Phylloxera*, has reported that none of the specifics submitted to them are entitled to the prize.

DR. EWALD records, in *Reichert's Archiv*, an instance of the production of a hydrocarbon gas in the stomach of a man suffering from chronic gastritis. The man, one day, while lighting a cigar, was surprised to see his breath take fire, and burn with a yellow flame. Dr. Ewald afterward analyzed some of this gas, and found it to consist of hydrogen, oxygen, nitrogen, carbonic acid, and a considerable portion (about ten per cent.) of marsh gas.

ABOUT ten per cent. of the Cape diamonds are of first quality, fifteen per cent. of second, twenty of third. The remainder are employed for cutting diamonds, and for the numerous applications of this gem in the arts. It is estimated that the value of the diamonds found at the Cape from March, 1867, to the present time exceeds £12,000,000.

DR. RICHARDSON, of London, cites the high death-rate of innkeepers, publicans, and the like, as evidence of the fatal effects of intoxicating drink. In London the mortality of all males is 2.012 per cent. annually; that of publicans, 3.466 per cent. In England, exclusive of London, the mortality of all males is 1.182 per cent. annually; of publicans 3.163 per cent. It is a striking fact that the death-rate in this class is higher than in any other class of male occupations named in the census, save one—the hackney-coachman.

SALICYLIC acid has been used with good results in Germany, in the treatment of recent superficial gangrenous sores, the method being to apply a thin layer of powdered salicylic acid on the surface of the sore, covering it then with wadding.

EXPERIMENTS lately made in France show that air laden with coal-dust is highly explosive. Several cases of explosion in coal-mines have been traced to the action of suspended coal-dust when no fire-damp was present.

THE practice of *scalping* is not peculiar to the American aborigines. Southall, in his "Recent Origin of Man," quotes from Herodotus to show that the Scythians used to scalp their fallen enemies. In the present time the wild tribes of Northeastern Bengal use the scalping-knife.

AN expedition under the leadership of Prof. Nordenskiöld will start next summer to explore a commercial route from Northern Russia to Behring Strait. Funds have also been contributed toward the cost of another expedition to explore the gulf of Obi and the sea-route between Archangel and the great rivers of Siberia.

EDMUND A. PARKES, M. D., F. R. S., Professor of Military Hygiene in the Army Medical School at Netley, England, died March 15th, at the age of fifty-six years. During the Crimean War he was selected by Government to organize and conduct a hospital, and on his return to England was appointed to the chair of Hygiene at Netley. His annual contributions on hygiene were for many years, perhaps the most valuable feature of the blue-books of the War Department. He was a very successful teacher, and a frequent contributor to the medical press, and to the "Transactions" of scientific bodies. His "Manual of Practical Hygiene" has reached a fourth edition.

DIED, March 29th, Dr. Henry Letheby, for many years lecturer on chemistry and toxicology in the London Hospital, and chemical analyst of the city of London. He was the author of a number of papers on sanitary and chemical subjects, published in sundry medical journals. His work on "Food" was republished in this country three years ago. At the time of his death he was sixty years of age.

NEARLY all the amber of commerce comes from Eastern Prussia, where it is obtained by dredging the bottom of the sea just off the coast. It was recently discovered that amber occurs in a deposit called the "blue earth." It has been supposed that this deposit extends for some distance inland, and a shaft was recently sunk to determine this point. At the depth of 140 feet there was found a stratum of "blue earth" without amber and two feet in thickness; then came another stratum five feet thick, which was rich in amber.

THERE are few who do not remember the childish wonder they once felt at hearing the resonance produced by placing a sea-shell to the ear, an effect which fancy has likened to "the roar of the sea." This is caused by the hollow form of the shell and its polished surface, enabling it to receive and return the beatings of all sounds that chance to be trembling in the air.—*Public Opinion.*

ALEXANDER BAIN.